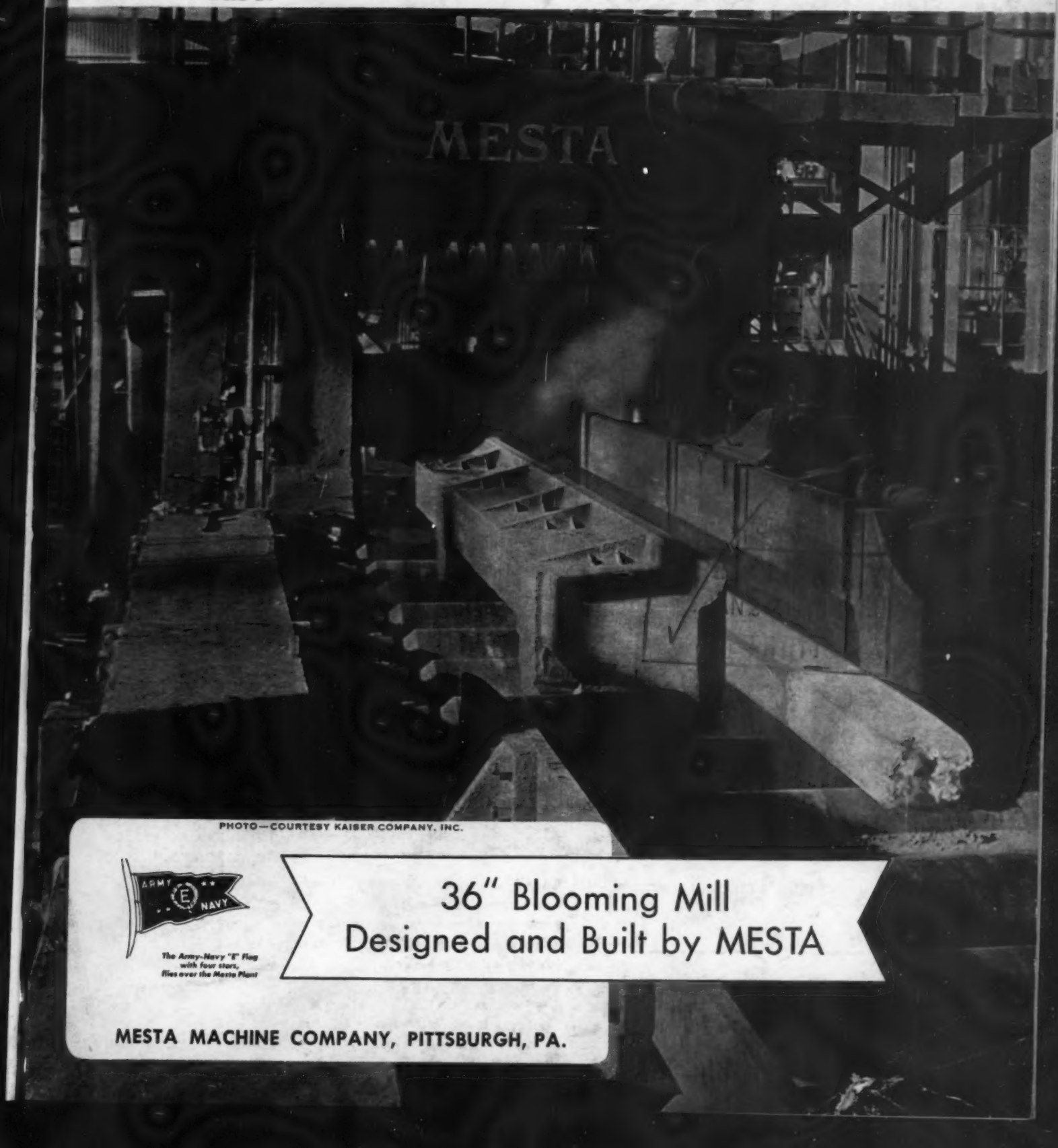
Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

1010 EMPIRE BUILDING — January, 1945 — PITTSBURGH, PA.

CHNOLOGY DEPT:



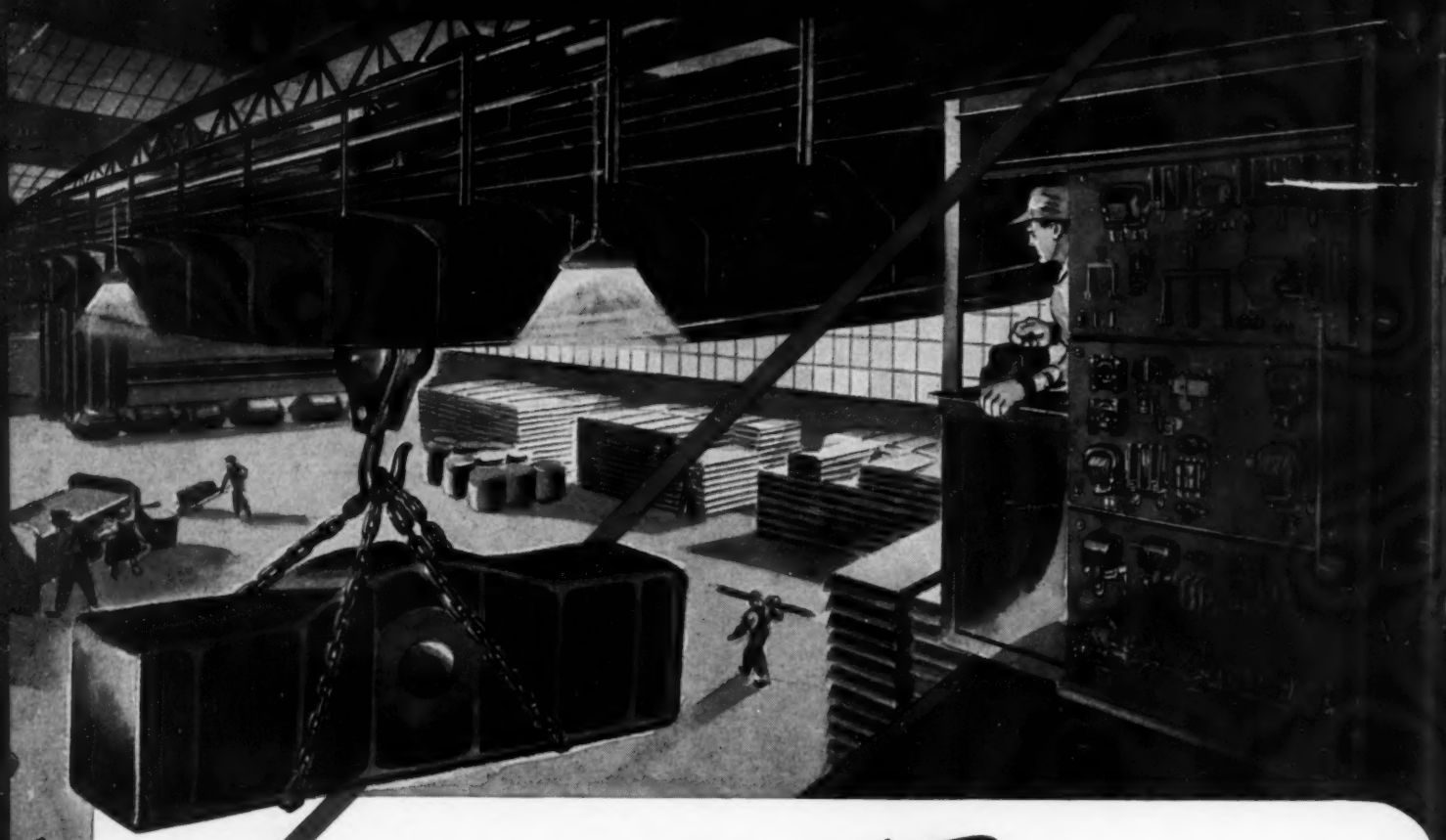
PHOTO—COURTESY KAISER COMPANY, INC.

ARMY E NAVY

The Army-Navy "E" Flag with four stars, flies over the Mesta Plant

36" Blooming Mill
Designed and Built by MESTA

MESTA MACHINE COMPANY, PITTSBURGH, PA.



For the first Time

FIVE DEFINITE AND STABLE LOWERING SPEEDS OF CRANE HOISTS

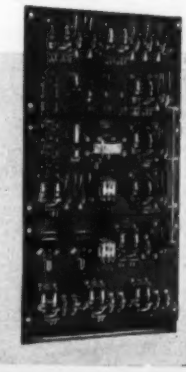
on Alternating Current

It is no longer necessary for crane users to turn to direct current when they want maximum crane hoist performance. It is no longer necessary to put up with costly, troublesome load lowering brakes on alternating current crane hoists. Cutler-Hammer Engineers have solved this problem . . . the problem of getting 5 stable selective speed points—both hoisting and lowering; full dynamic braking; accurate inching; timed acceleration in both directions and timed deceleration for spotting a load . . . *all on alternating current.*

This new Cutler-Hammer AC Crane Control can be used with any standard slip ring crane motor and is available in drum type manual and magnetic types. Specify this outstanding engineering development for your next crane. Write today for full information. CUTLER-HAMMER, Inc., 1269 St. Paul Avenue, Milwaukee 1, Wisconsin. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto, Ont.

CUTLER·HAMMER
MOTOR CONTROL
C-H

Control engineering ingenuity solved the long-standing problem of how to get crane performance on alternating current. This control panel of standard C-H units does the job with a standard AC motor.



Engineering Excellence finds its Greatest Reward in the Respect and Confidence of those it Serves

other Aetna-Standard Product

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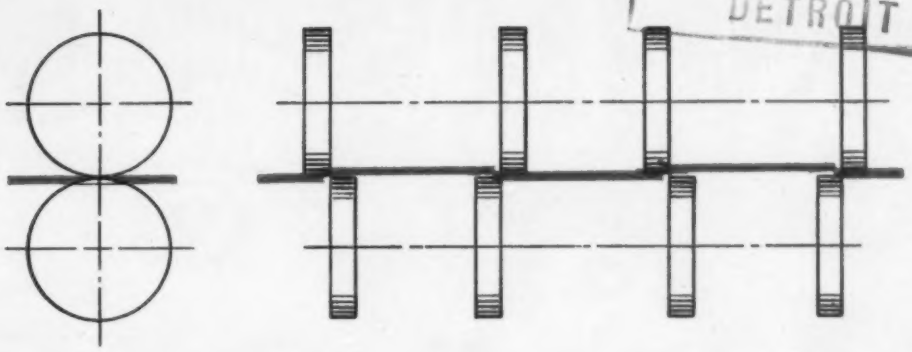


Slitting and Side-Trimming Equipment

From Aetna-Standard you can buy a size and type of slitter or trimmer for handling the more popular sizes of sheets and strip. Perhaps you prefer a machine on which both operations of slitting and trimming can be done.

Only a few minutes are needed to switch from slitting to trimming or the reverse. For side-trimming, the knives fasten to the overhanging spindles. To change over to multiple slitting, the knives and spacers, mounted on arbors, drop into tapered bores in cast steel housings. These housings are adjusted to the center line of pass by means of motor operated screws. The unit cuts accurately within standard tolerances and operates at varying speeds up to 500 f. p. m. It is also equipped with a scrap cutter.

When slitting and trimming equipment comes up for consideration in your plant, check Aetna-Standard.

Aetna-Standard makes many sizes and types of slitting and side-trimming equipment, also combination side-trimmers and multiple slitters

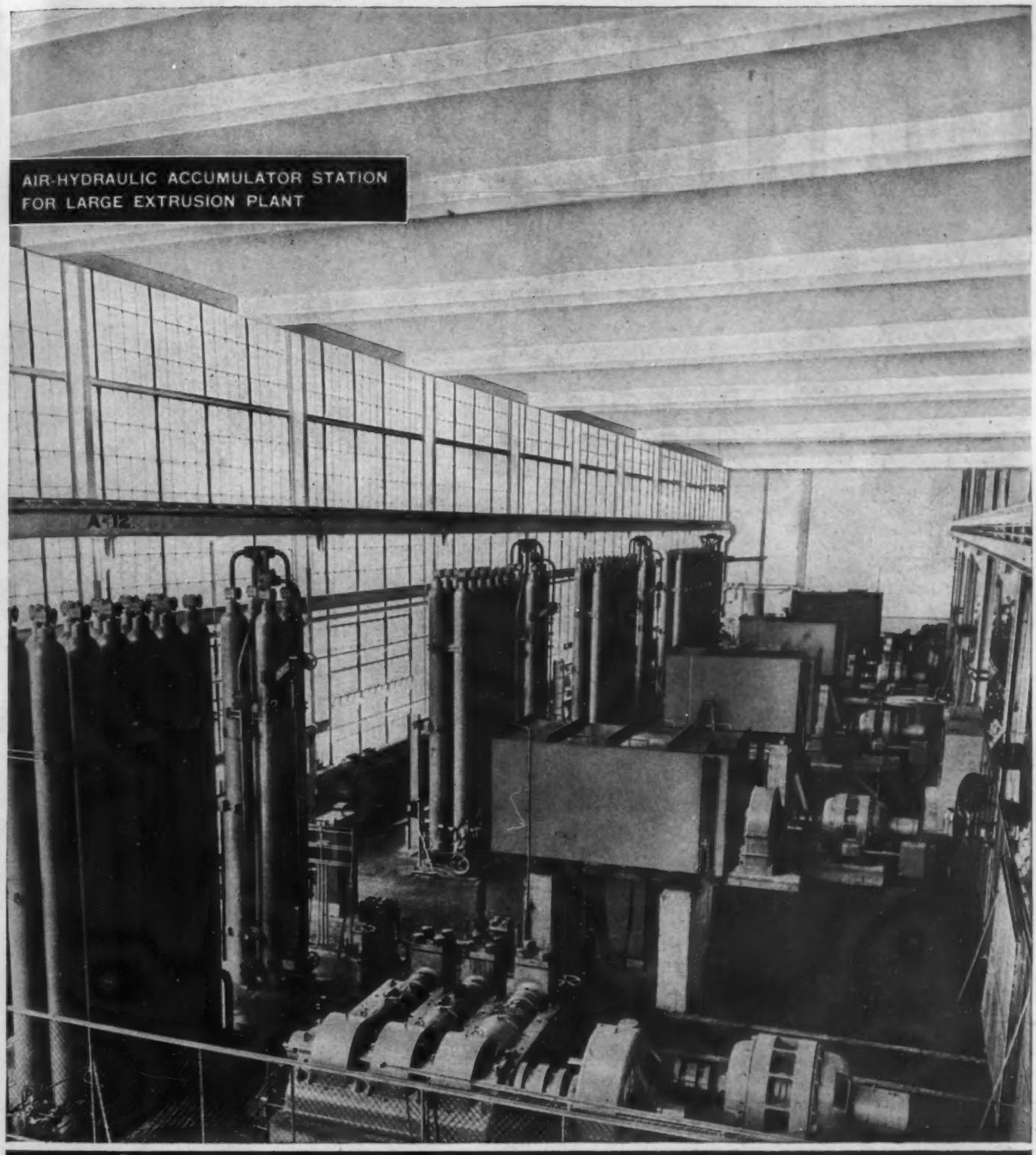
THE AETNA•STANDARD
ENGINEERING COMPANY
YOUNGSTOWN, OHIO

DESIGNERS AND BUILDERS to the Steel, Non-Ferrous and Chemical Industries.

ASSOCIATED COMPANIES:
HEAD, WRIGHTSON & COMPANY, LIMITED, THORNABY-ON-TEES, ENGLAND
JOHN INGLIS COMPANY, LIMITED, TORONTO, ONTARIO, CANADA

The NATIONAL ROLL & FOUNDRY CO.

General Offices and Plant . . . AVONMORE, PENNSYLVANIA



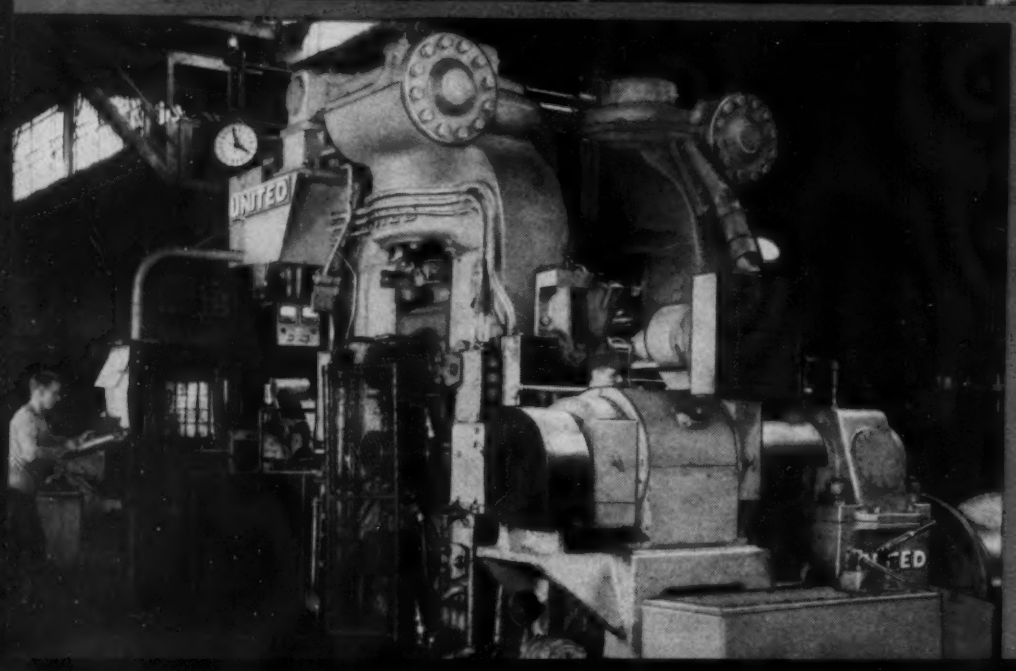
HYDROPRESS · INC.

ENGINEERS CONTRACTORS

HYDRAULIC PRESSES · ROLLING MILLS
STRETCHERS · PUMPS · ACCUMULATORS

570 LEXINGTON AVENUE · NEW YORK · N. Y.

UNITED presents another first



Above—Delivery Side of United Unitemper Mill.

Left—Entry Side of United Unitemper Mill.

the UNITEMPER MILL*

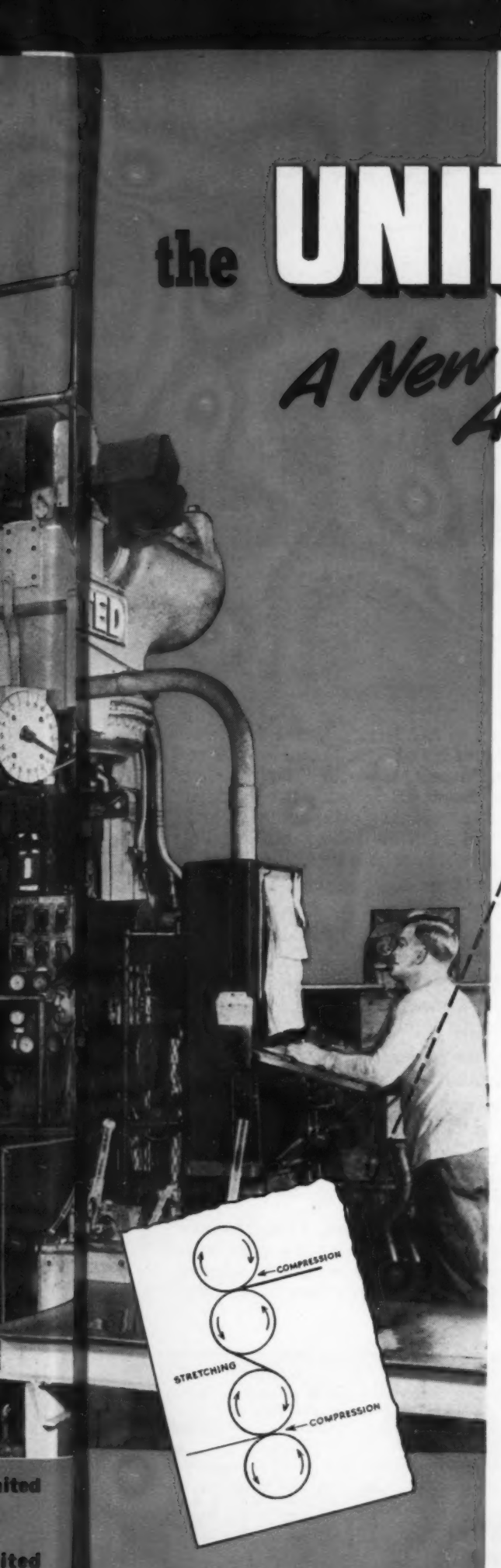
A New Mill... A New Process... A New Product

★ **Simplest Mill Arrangement to Produce All Commercial Degrees of Temper Hardness**

★ **Permits Standardization of Ingot Analysis**

★ **Produces a Flatter Strip with Better Cold Forming Properties**

★ **Produces at Lower Costs**



This mill resembles somewhat in appearance a conventional 4-high mill. It employs in a single housing two pair of processing roller and tensioning units disposed vertically with respect to one another and between which the strip is processed by stretching, the strip passing in a circuitous path around these units. This stretching is accomplished by regulation of the differential in speed between the upper and lower roller tension units. In the mill the strip is reduced continuously in a sequence of operations consisting of rolling, stretching, and again rolling, the major portion of the reduction being accomplished by stretching and the processing being varied as required to secure different degrees of hardness.

UNITED UNITEMPER MILL utilizes the principle of **work-hardening or tempering by continuous stretching.** The resultant product, uniformly cold-worked throughout its entire thickness, conclusively shows superior cold-forming properties as well as meeting all accepted physical standards.

All commercial degrees of hardness can be made with one pass through the UNITEMPER MILL, using one grade of rimming steel. Standardization of ingot analysis, with its attendant economies, is therefore possible.

The UNITEMPER process, which embodies all of the essentials of continuous stretcher leveling, produces an **extremely flat product.**

Extremely low rolling pressures, as compared with conventional 4-High Temper Mills, permit use of UNITED Alloy Iron Rolls instead of more expensive forged steel rolls. This, plus savings resulting from **standardization of ingot analysis,** and savings due to a **simpler installation,** make the UNITEMPER process extremely attractive from a manufacturing standpoint.

To manufacturers of tinplate, autobody sheets, furniture stock, stainless steel panels and other specialties, in anticipation of demands for hard-rolled steel with better cold-forming properties for many fabrications, the revolutionary advantages of UNITEMPER will be apparent.

UNITED engineers will gladly furnish complete information including data based on mill production records.

** Process and apparatus patents pending.*

UNITED ENGINEERING AND FOUNDRY CO.

PITTSBURGH, PENNSYLVANIA

Plants at PITTSBURGH · VANDERGRIFT · NEW CASTLE · YOUNGSTOWN · CANTON

Davy and United Engineering Company, Ltd., Sheffield, England

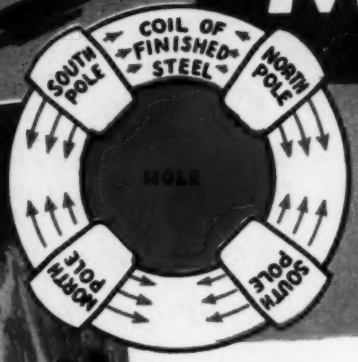
Dominion Engineering Works, Ltd., Montreal, P. Q. Canada

** The World's Largest Designers and Makers of Rolls and Rolling Mill Equipment*

WHEN PLANNING FOR *Reconversion*

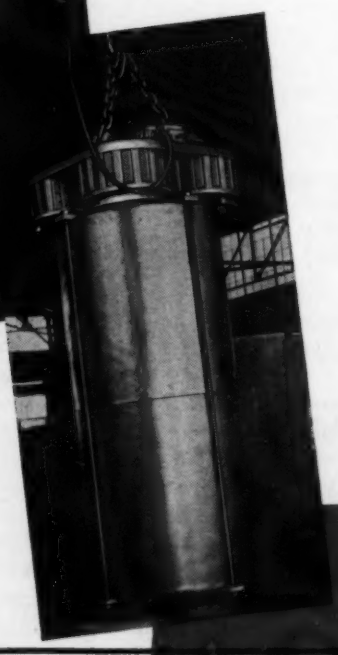
— remember to *INCLUDE*

The EC&M TYPE CSM MAGNET



...FOR COLD STRIP COILS

● EC&M Type CSM Magnet (No. 6) lifting two coils weighing 56,600 pounds —*the World's Biggest Lift of Coiled Steel.*



● This EC&M No. 2 Type CSM Magnet is shown in the above illustration, placing a coil on the annealing bottom.

Designed to *lift the coil,* not the hole. No mass of metal over the hole and no concentric pole shoes limiting the flux path in the coil. Instead, this modern magnet combines compactness and small weight with lifting ability distributed *within the coil itself.*

Its advantages for *finished* coil handling are:

1. Magnetic flux concentrated in the coil to be lifted.
2. *Balanced load*—less danger of injury to bottom of coil when depositing coil.
3. Magnet is smaller than other coil handling magnets, weighs less.
4. Magnet does not hide the view of the crane operator.
5. Magnet fits the coil with minimum overhang resulting in increased storage capacity.
6. Less damage to edges of coil because of wide pole shoes which span coil-turns and because weight of magnet is less and is evenly distributed over coil surface.

For handling *Raw* Coils, other EC&M Magnets are available. Information on request.

THE ELECTRIC CONTROLLER & MFG. CO.

2698 EASTH 79TH STREET CLEVELAND 4, OHIO

CALL IN THE FLUOR 'SPECIALIST' NOW!

This summer's operating records show what your water cooling requirements were during warm weather peaks. To be sure you maintain the efficiency of your Cooling Towers to meet next summer's demands, let Fluor make this vital Maintenance Check-Up during the colder months ahead while demands on your towers are lessened:

1. Inspect decks and filling for sagging, accumulation of foreign matter, loss of parts, etc.
2. Inspect distributing system for scale, rust, clogging, leaks, loss of pressure, etc.
3. Determine quality and quantity of water flow. Look for rapid corrosion of metal parts and delignification in the wood.
4. Check flow of effluent air for recycling troubles in mechanical draft towers.
5. Inspect ladders, handrails, stairs and walkways for signs of weakening.
6. Inspect structural members including bolts and castings for cracks, breaks and other causes of failure.
7. Check motors, pumps, gears, fans, couplings and other mechanical equipment.

FLUOR Maintenance and Repair Service covers ALL MAKES and TYPES of Cooling Towers. As manufacturers of Fluor Aerator and Fluor Induced Draft Cooling Towers, Fluor M & R Service is complete and economical.

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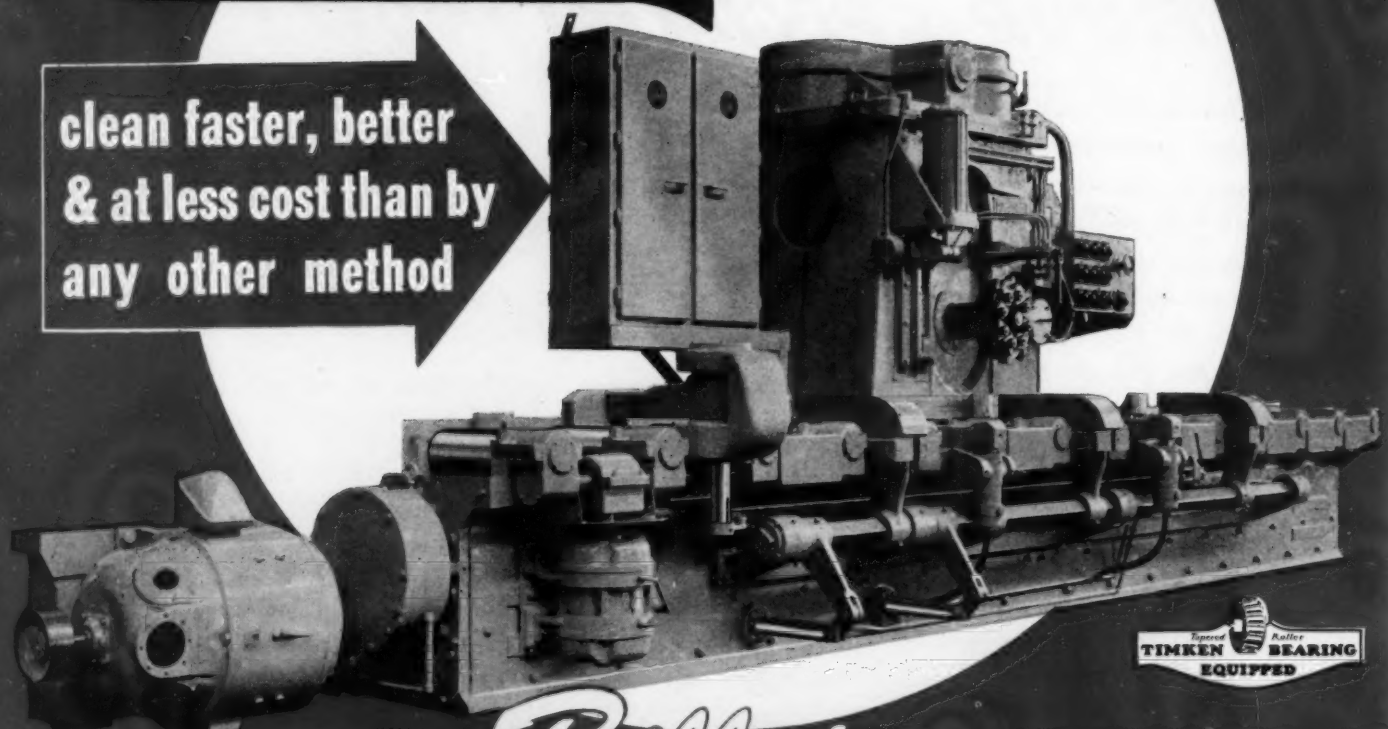
If you Judge Mill Equipment by its Savings Per Ton, We Have User Facts That Prove Billeteers will—

FASTER BETTER LESS COST

clean faster, better & at less cost than by any other method



Tapered Roller TIMKEN BEARING EQUIPPED

INVESTIGATE *Billeteer* ECONOMIES

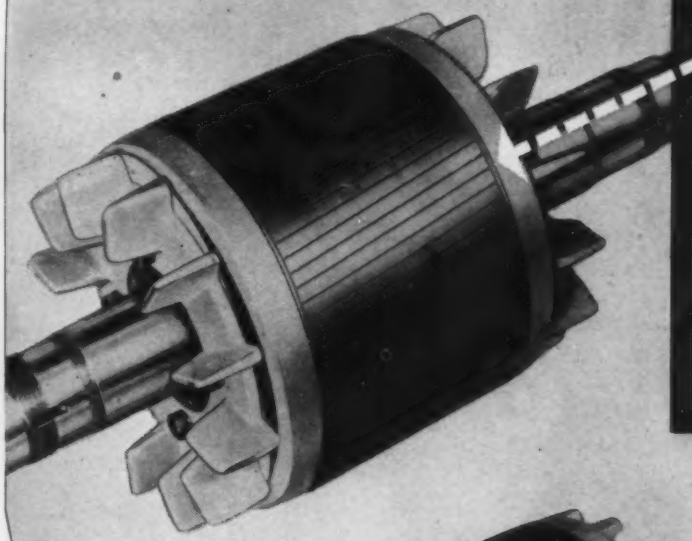
STEEL EQUIPMENT DIVISION OF **THE BONNOT COMPANY, CANTON, OHIO**

BONNOT

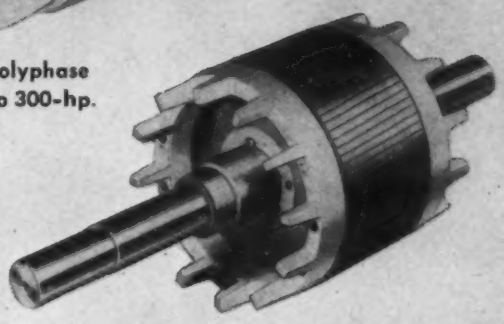
ENGINEERED FOR IMPROVED PRODUCTION

WRITE FOR COMPLETE FACTS

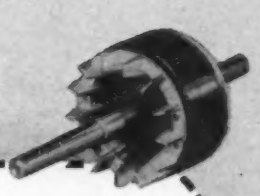
Cast Aluminum Rotor Construction GIVES LONG LIFE TO Wagner MOTORS



Rotor for polyphase motors 40 to 300-hp.



Rotor for polyphase motors 5 to 30-hp.



Rotor for polyphase motors 1/6 to 3-hp.

Hundreds of Thousands of Wagner Motors with Cast Aluminum Rotors have been built during the past 25 years and are giving perfect satisfaction.

★

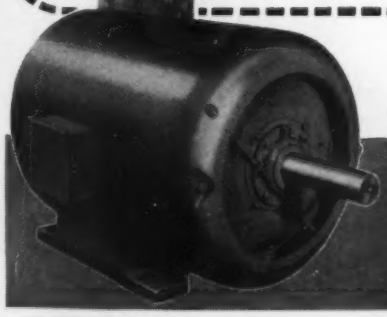
Rotor for split-phase motors 1/20 to 1/3-hp. and capacitor motors 1/8 to 3/4-hp.

Rotor for shaded-pole fan motors 1/125 to 1/30-hp.

- Wagner squirrel-cage rotors are cast under heavy pressure. The aluminum completely fills the rotor slots and tightly clamps the punchings.
- The rotor bars and endrings make complete and intimate contact with the core-iron, facilitating heat-transfer and absolutely eliminating squirrel-cage vibration.
- The squirrel-cages in all Wagner general-purpose motors are practically pure aluminum of high conductivity and ductility They successfully withstand the most severe service because they are not affected by repeated heating and cooling and they cannot vibrate.
- A special patented construction is used in the medium and larger sizes to reduce the load losses and increase the motor efficiency.

The mechanical and electrical characteristics, inherent in cast aluminum rotors, have contributed in a large measure to the reputation for quality and dependability established by Wagner motors for the past 50 years.

Write for complete literature



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Each of these offices is manned by trained field engineers ready to help you solve your motor-drive problems.

M45-4

Wagner Electric Corporation

ESTABLISHED 1891

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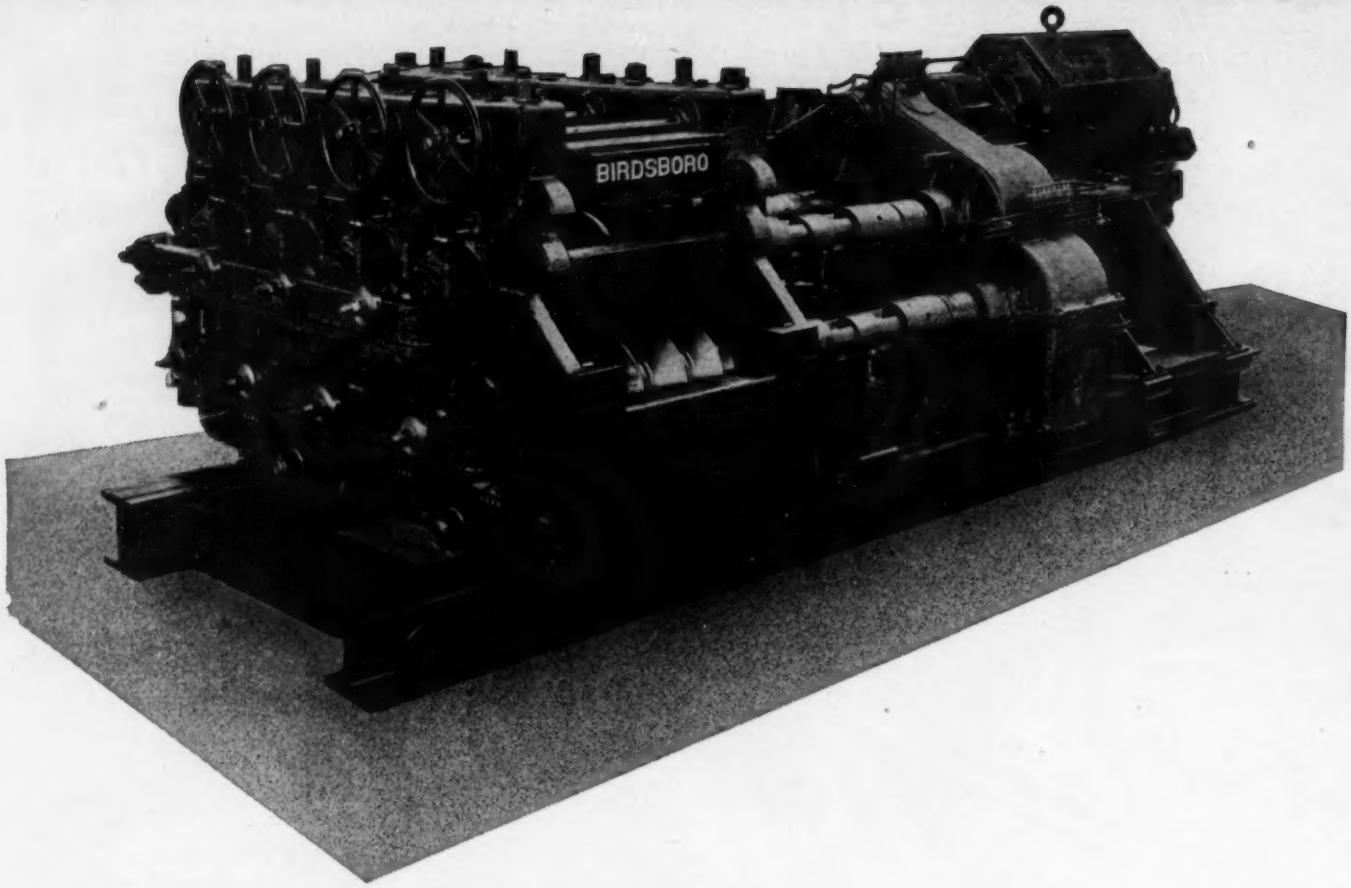
ELECTRICAL AND AUTOMOTIVE PRODUCTS



How to Accurately Straighten 6" x 6" or Smaller Angles

The job of accurately straightening 6"x 6" angles or equivalent shapes is made easy when you have a Birdsboro structural shape straightening machine in your mill. This machine is equipped with eight straightening rolls, four top and four bottom, each driven. In addition, a patent roll end adjustment permits quick and convenient regulation from the outside while the machine is in operation. Individual vertical adjustments of top rolls are also possible by means of hand-operated worms and gears.

BUY WAR BONDS

Birdsboro specializes in building steel mill equipment for heavy-duty work, and is ready to help you with your specific problems. Write us today for further information on our services.

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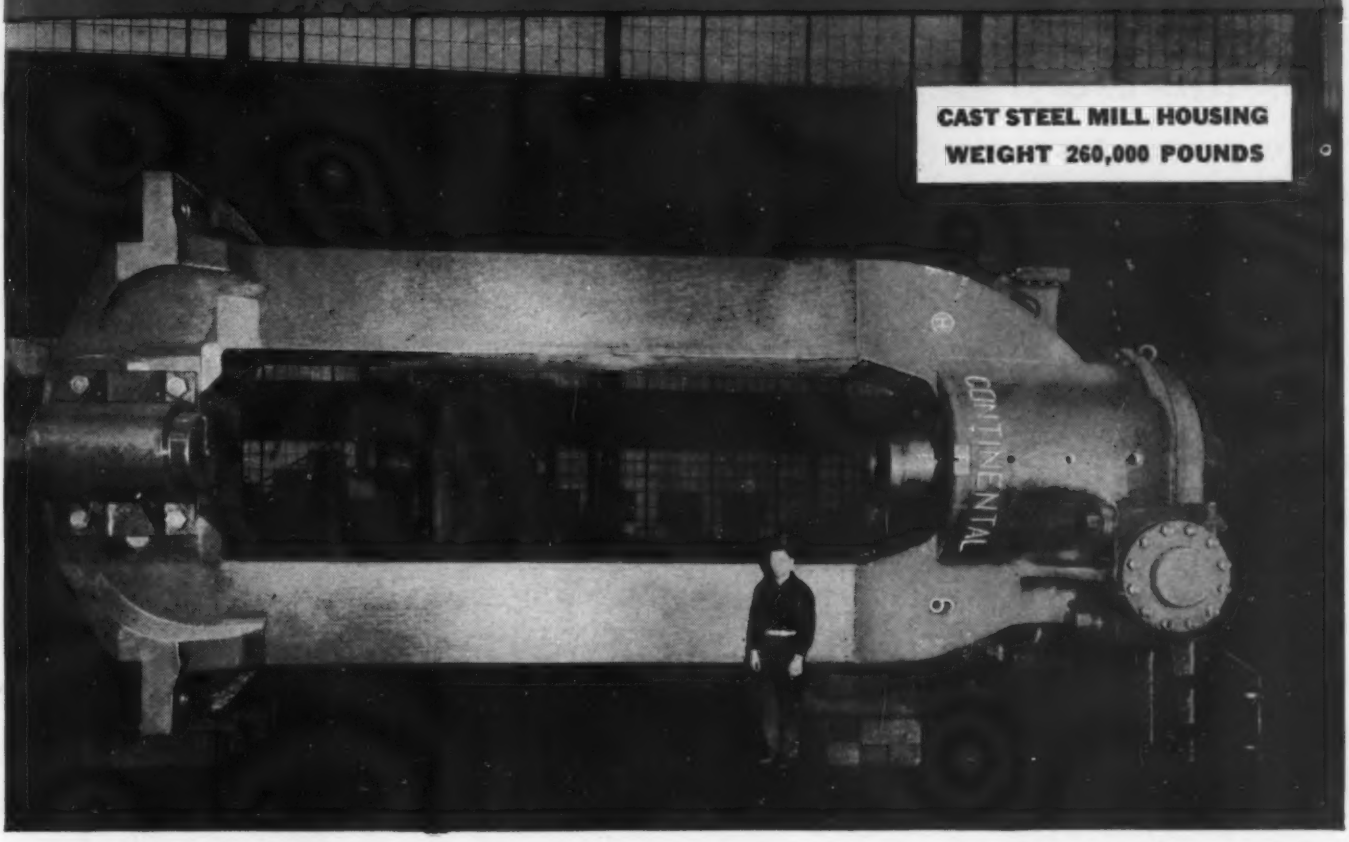
BIRDSBORO

STEEL MILL EQUIPMENT

CONTINENTAL

CARBON AND ALLOY STEEL CASTINGS



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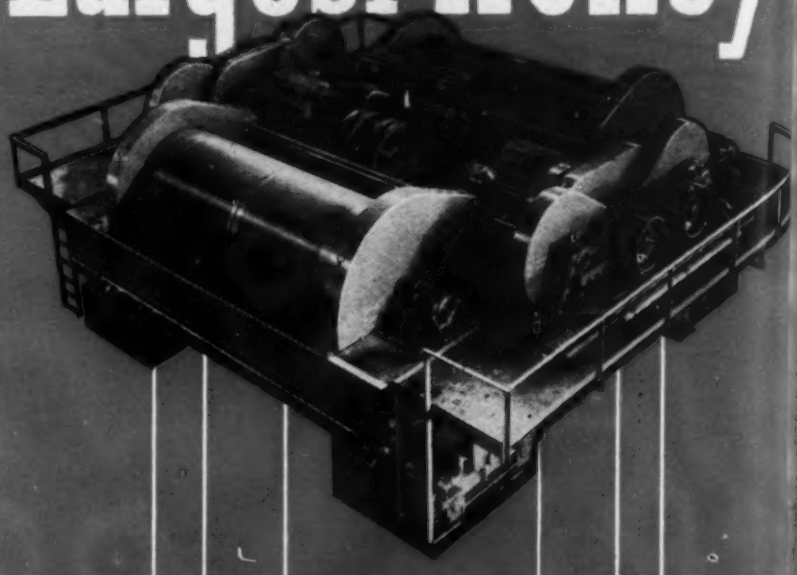
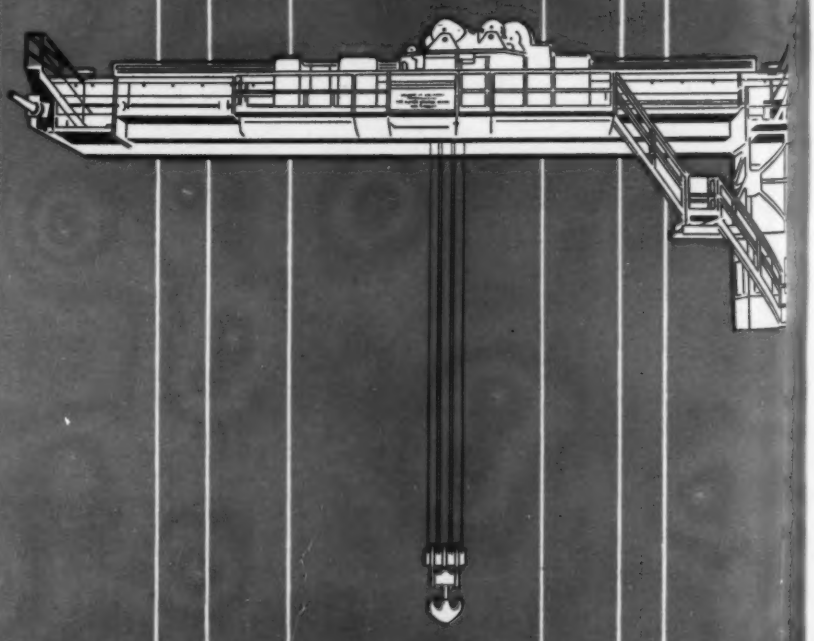
BUILT BY THE WORLD'S LARGEST BUILDERS OF THE WORLD'S LARGEST CRANES . . .

The World's Largest Trolley





● Drafted for service in World War I. three of these 336 ton 90' 0" span cranes now have a service record of 27 years without furlough.

When the present world conflict called for increased facilities to equip our forces with the necessary armament, it was only logical that Alliance would be asked to furnish *exact duplicate cranes,* as the maintenance record showed practically no repairs during their many years of service.

Five of these lifting giants are now carrying the war loads for Uncle Sam.

These cranes have multiple drums, high speed lowering on the auxiliary hoist, and are designed for a lift of 100 feet.

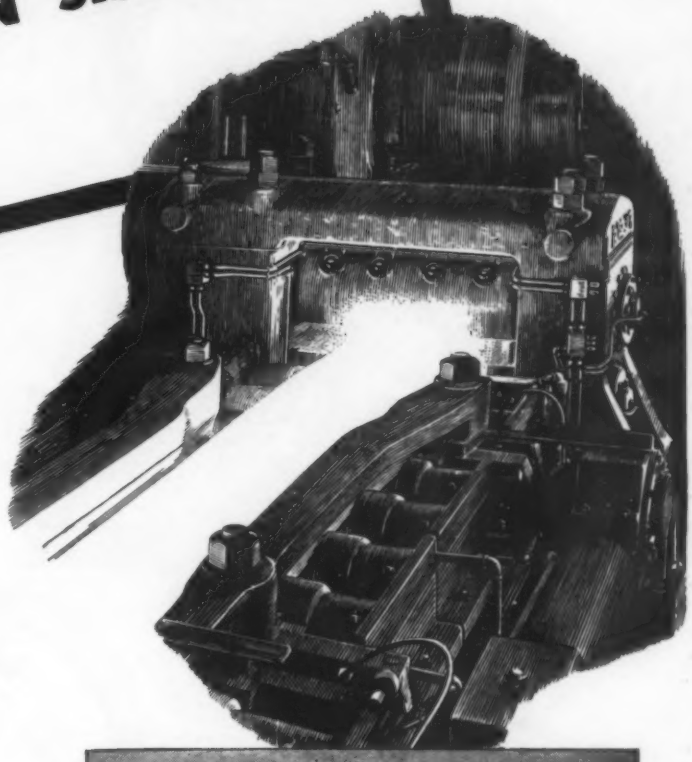
★

Ladle Cranes • Gantry Cranes • Forging Manipulators • Soaking Pit Cranes • Stripper Cranes Slab and Billet Charging Machines • Open Hearth Charging Machines

THE ALLIANCE MACHINE CO.
ALLIANCE, OHIO
PITTSBURGH, PA., OFFICE—1622 OLIVER BLDG.

Alliance

FOR ACCURACY IN SHEARING



Mesta Flying Shear Installed in an 80-inch Continuous Hot Strip Mill

The flying shear of this continuous hot strip mill entrusts its heavy operating loads to Torrington Roller Bearings. Built to take the around-the-clock punishment imposed by the high speed operation of this modern strip steel cutter, these high capacity bearings provide the necessary accuracy in shearing so that edges are clean and lengths are cut within specified tolerances.

Today, Torrington Bearings are helping to ease the work of many types of steel mill equipment in roughing breakdown mills, rolling mills and continuous hot strip mills. The broad experience of Torrington engineers is available in designing and manufacturing bearings "tailored" to fit your specific requirements.

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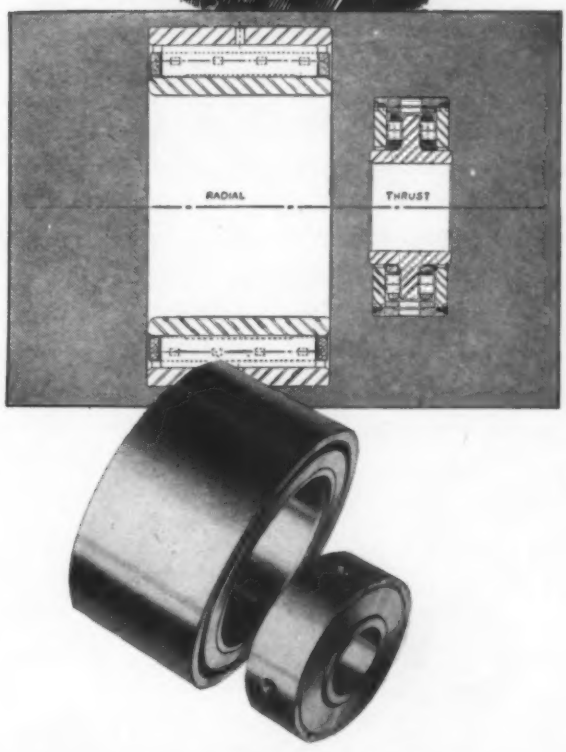

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STRAIGHT ROLLER · TAPERED ROLLER · NEEDLE · BALL

Number 7 of a Series: **"Looking at the 5 essential things you never see in electrodes!"**

DEMAND Control

A BASEBALL PITCH can win a game. Coal-tar pitch can affect an electrode. Both kinds of pitch demand *control!* We control our kind of pitch and the other raw materials, throughout the many steps required to make them ready, to blend them, and finally to convert them into tough electrodes for duty in your electric furnaces.

At National Carbon Company, this rigid program of *manufacturing control* helps to make your "National" carbon and "Acheson" graphite electrodes uniform in strength and electrical conductivity . . . it has also been instrumental in steadily cutting the average price of electrodes—approximately forty per cent for graphite since 1922.

But manufacturing control is just one of the "five essential things you never see," but should demand, in electrodes. The others: Manufacturing experience, raw materials selection, customer service, and continuing research. "National" and "Acheson" electrodes have all five. Your inquiries are invited.

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Experimental Rolling of Flats and Shapes

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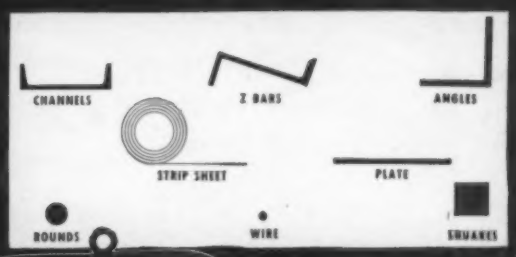
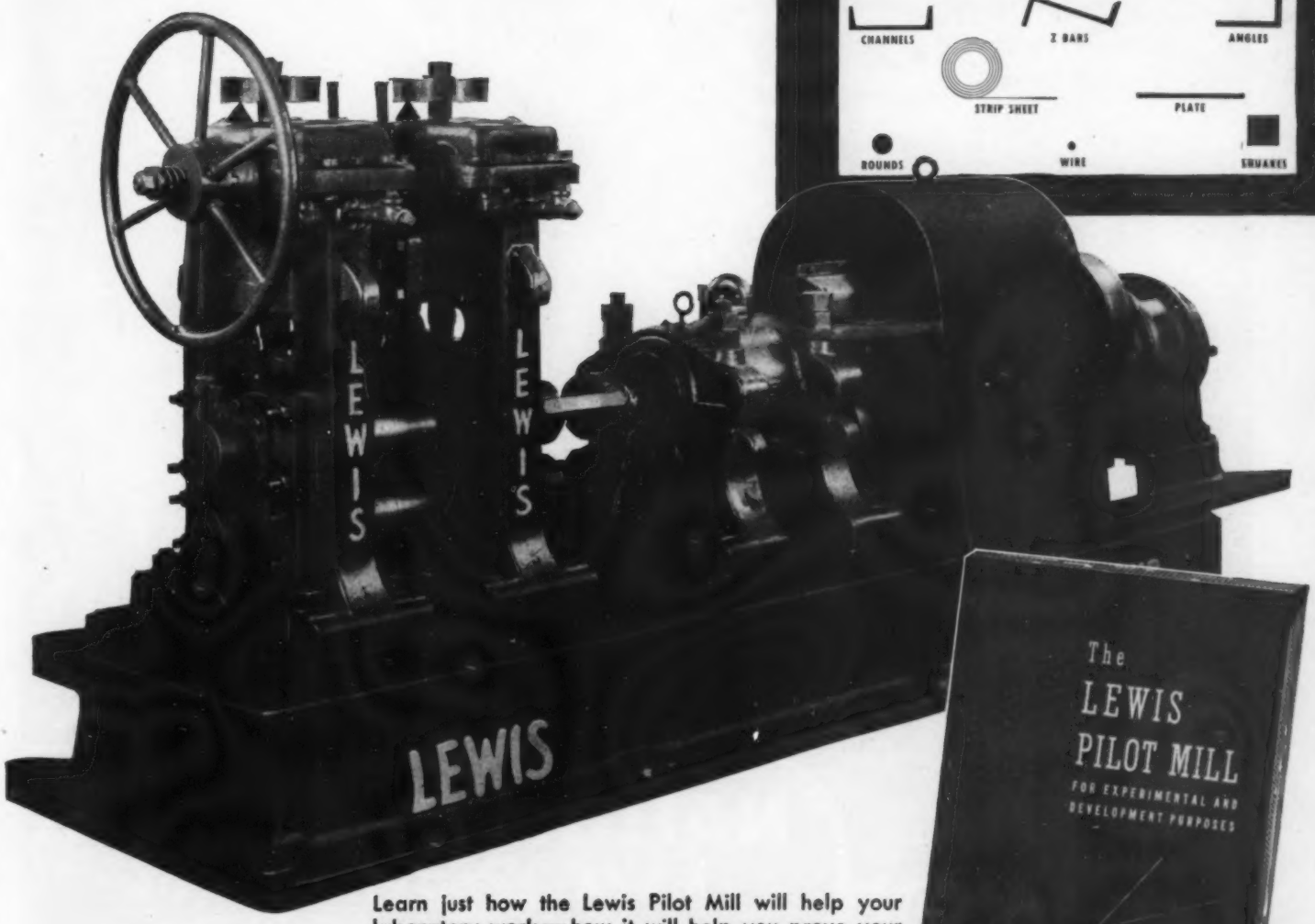
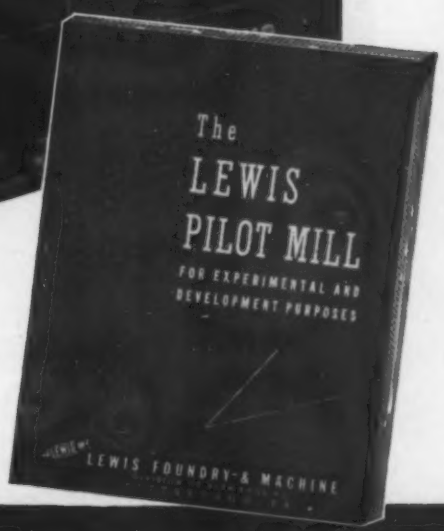
At a minimum of capital risk you can now compile invaluable data on rolling techniques required for the new alloys of steel, aluminum, magnesium, brass, copper, zinc, etc., through laboratory trials on this versatile pilot mill. It is capable of rolling Channels, Z-Bars, Angles, Strip Sheet, Plate, Rounds, Wires and Squares.







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Here only the *best* can meet the test. Only supreme stamina can withstand this withering trial by fire.

For seventy years N-B-M has kept step with the progress of the steel industry, perfecting new and tougher alloys to meet more exacting needs. Our extensive experience is your guaranty of satisfaction when you specify

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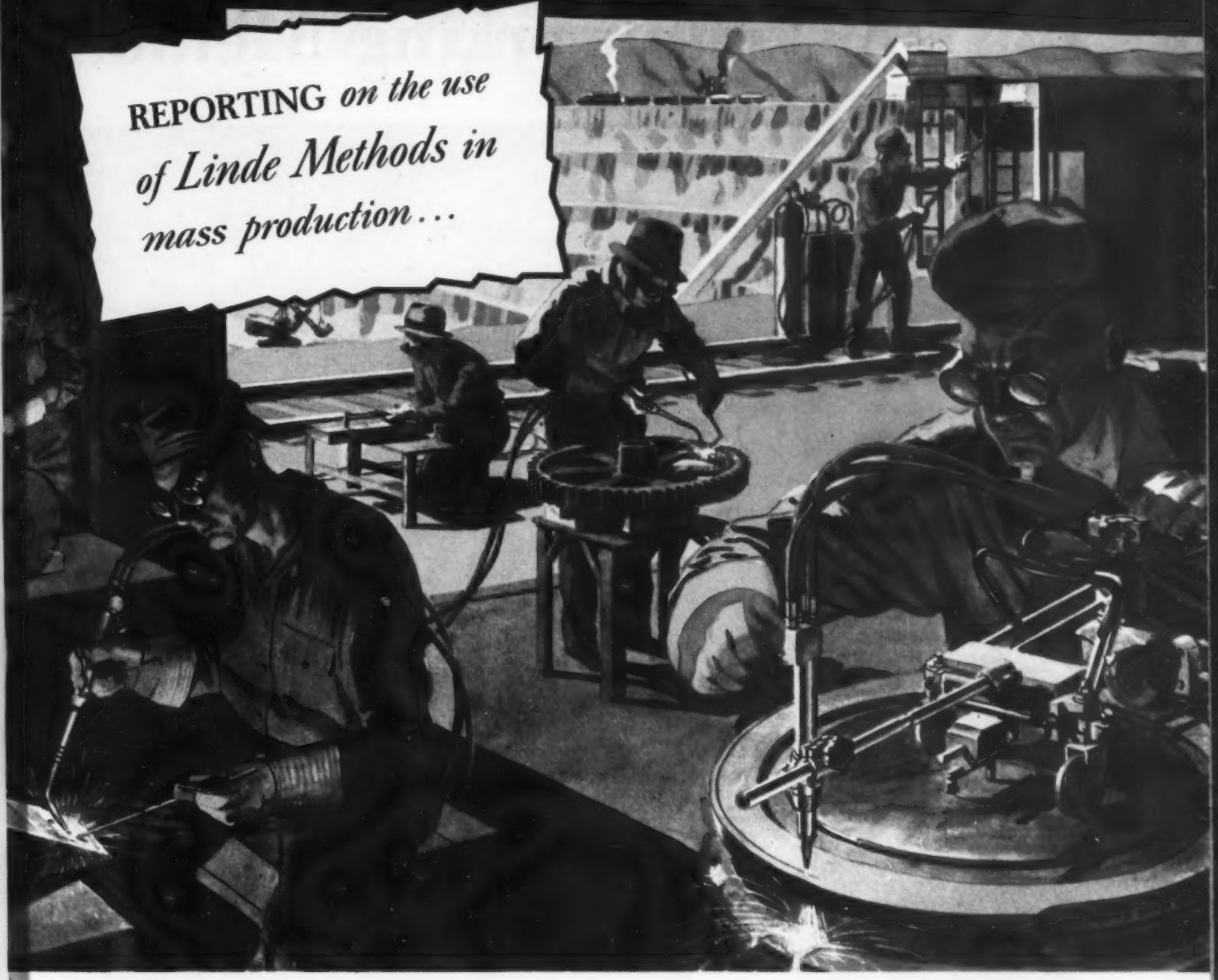
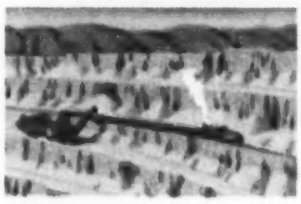
REPORTING *on the use of Linde Methods in mass production . . .*





Production and Fabrication of Steel . . .

through the entire cycle from mining to scrapping, LINDE METHODS are important

The oxy-acetylene processes shown here—flame-cutting, flame-cleaning, flame-gouging, welding, and hard-facing—are a few of the many Linde processes that are important in the entire cycle of steel. In iron mines . . . in mills where steels are made . . . in fabricating shops . . . even in scrap yards where worn-out equipment is prepared for further service . . . Linde developments help to speed production and lower costs.

In this mine maintenance shop, for example, the equipment is kept in good operating condition by the use of some of these Linde processes. The portable oxy-acetylene cutting machine used here to reclaim a worn locomotive wheel is also used to produce steel shapes from stock steel.

There are other Linde methods to help maintain production . . . methods for hard-facing parts such as dipper teeth . . . for gouging out cracks in castings to prepare them for welded repair . . . and for flame-priming structural steel and plate to make paint last longer when it is applied.

In the next three pages you can learn more about the use of Linde-developed processes in the mass-production of steel and things made of steel.

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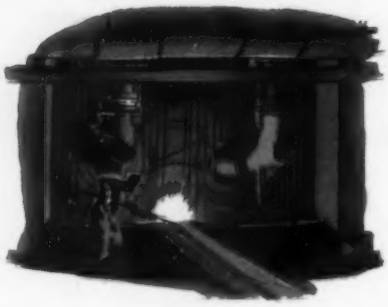
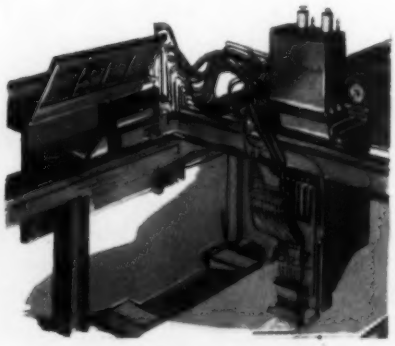
LINDE Metalworking Methods



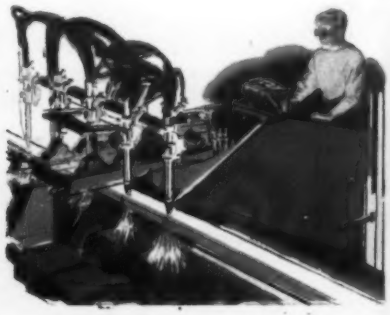
Furnace-Tapping—By use of the oxygen lance to clear the tap hole, the opening is quickly made for molten iron or steel to pour from the furnaces.

MECHANIZED HOT-SCARFING — The removal of surface defects from semi-finished steel once entailed removing the hot steel from the production line . . . allowing it to cool . . . treating it to make defects visible . . . or chipping out these defects . . . and then reheating the steel for further processing. Today, through use of Linde equipment, mechanized batteries of oxy-acetylene blowpipes located on the roll tables literally "skin" faulty surfaces from the hot steel . . . and higher yields of quality steel are obtained without interruption of production.

Deseaming — Where mechanized conditioning of steel is not feasible, or for secondary conditioning, Linde's manually operated flame - scarfing equipment is used.

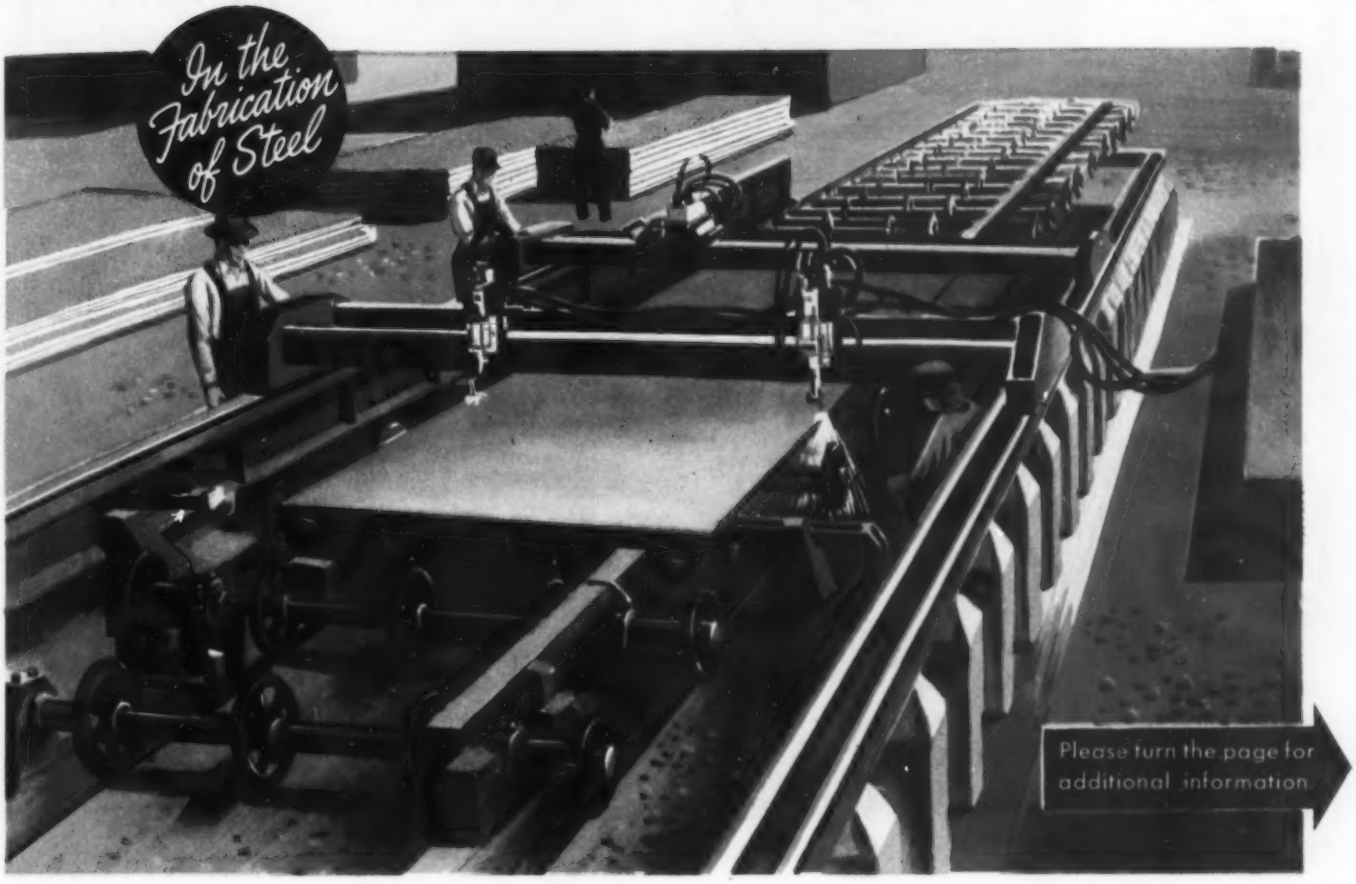


Mechanized Cold-Scarfing —Some special steels, such as slabs of armor plate, are allowed to cool before scarfing by Linde machines that move along the slab.



Billet-Cutting — Flame-cutting machines developed by Linde are used in the production line to cut billets and bars to length quickly, several pieces at a time.

. . . Save Time and Materials



MECHANIZED FLAME-CUTTING — For shaping steel in the fabrication of industrial machines and equipment oxy-acetylene cutting is effecting important savings, both in time and in materials. The oxy-acetylene flame quickly and accurately slices through steel in straight lines, circles, or irregular shapes . . . work that otherwise would require massive machines. Linde engineering skill has helped adapt this "knife that never dulls" to high-speed work like the flame-planing of ship steel shown here. In one operation plate edges are trimmed to exact size and beveled like this ▬◣ for welding.

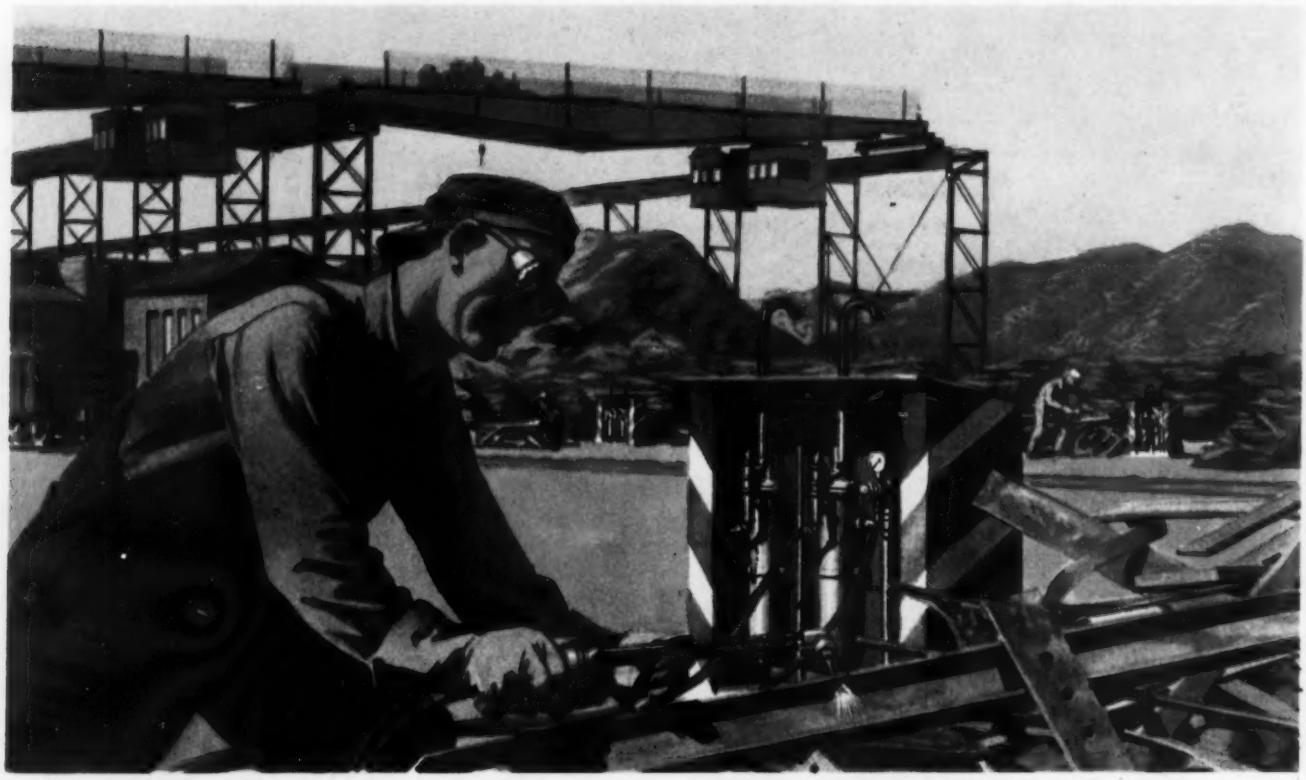
Tube-Welding—In making welded tubing, edges of steel strip moving at high speeds through forming rolls are joined by oxy-acetylene flames.

Unionmelt Welding—Linde's automatic electric welding process makes high-quality welds in steel of any thickness at unusually high speeds.

Flame-Hardening — Oxy-acetylene flames, followed by a water quench, impart a hard, wear-resistant case to surfaces of carbon or alloy steel parts.

Flame-Spinning — Tubing heated by oxy-acetylene flames while spun rapidly can be quickly end-formed to eliminate deep-drawing operations.

LINDE METHODS help to complete the cycle of steel and things made of steel



On the three preceding pages you have seen how Linde-developed processes and equipment speed the production of steel and things made of steel . . . from the mining of ore through all phases of fabrication. When steel products have served their useful life, oxy-acetylene processes help to complete the steel cycle. Flame-cutting with manually operated blowpipes is a fast and economical way to reduce steel to pieces of the right size for charging into furnaces for the production of new steel. During this work, many usable parts and steel sections can be salvaged for reclamation by welding and put back into service.

In whatever way you may work with steel it is likely that Linde engineering skill can help you adapt the oxy-acetylene flame to your operations.

The folders shown at the left tell the story of the use of Linde methods in SHIPBUILDING, in STEELMAKING, in METAL-FABRICATING, and in the production of PIPE. Copies will be sent to you upon request. Ask for Combination "B".

MARITIME "M" AWARD FOR OUTSTANDING PRODUCTION ACHIEVEMENT

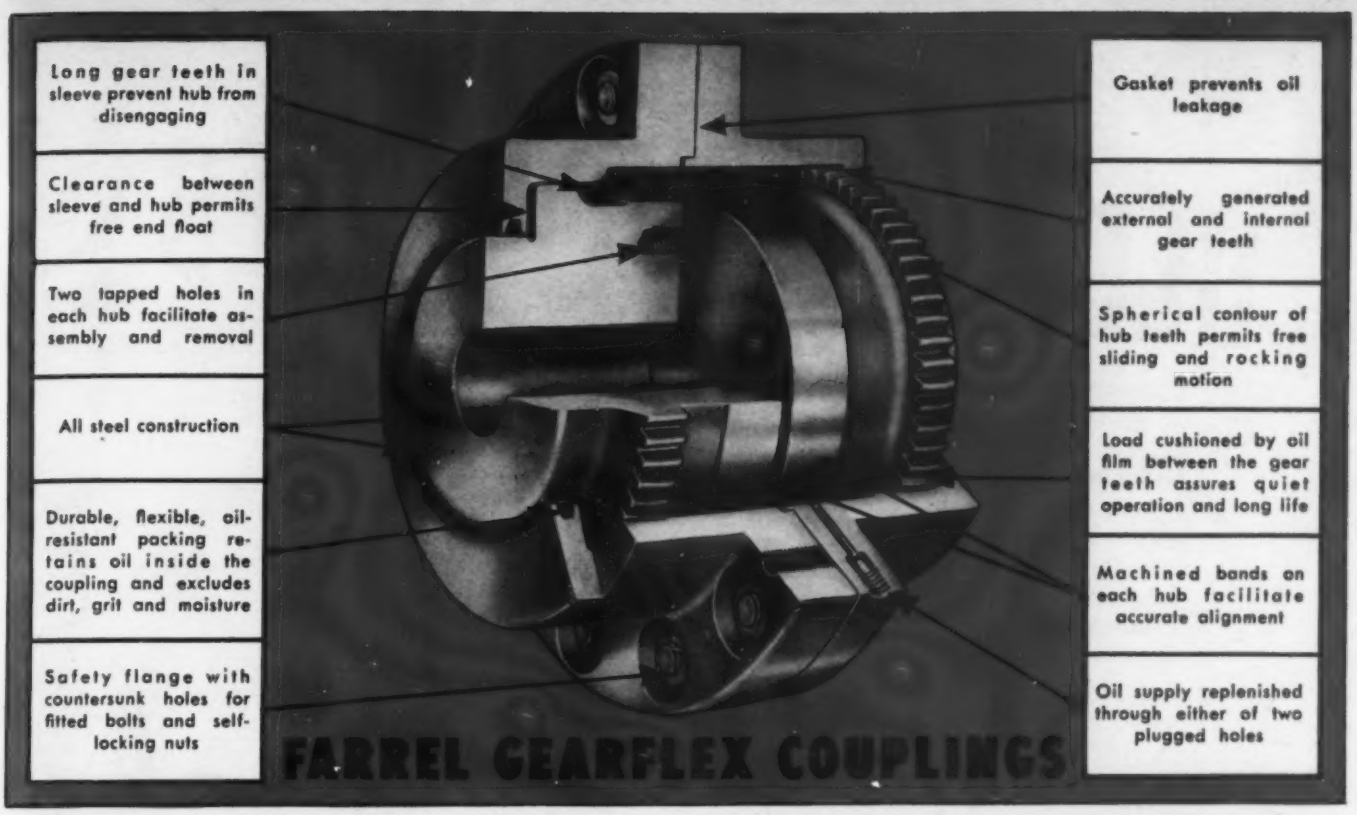
THE LINDE AIR PRODUCTS COMPANY

Unit of Union Carbide and Carbon Corporation

30 E. 42nd St., New York 17, N. Y. UCC Offices in Other Principal Cities

In Canada: Dominion Oxygen Company, Limited, Toronto

★ BUY UNITED STATES WAR BONDS AND STAMPS ★


Long gear teeth in sleeve prevent hub from disengaging
Clearance between sleeve and hub permits free end float
Two tapped holes in each hub facilitate assembly and removal
All steel construction
Durable, flexible, oil-resistant packing retains oil inside the coupling and excludes dirt, grit and moisture
Safety flange with countersunk holes for fitted bolts and self-locking nuts
Gasket prevents oil leakage
Accurately generated external and internal gear teeth
Spherical contour of hub teeth permits free sliding and rocking motion
Load cushioned by oil film between the gear teeth assures quiet operation and long life
Machined bands on each hub facilitate accurate alignment
Oil supply replenished through either of two plugged holes
FARREL GEARFLEX COUPLINGS

FOR STEEL MILL APPLICATIONS

The Farrel Gearflex meets every requirement of a flexible coupling. It compensates for angular, offset and combination misalignment of shafts; offers no hindrance to axial float; is simple to install, easy to align, and can be disconnected with ordinary tools without endwise movement of either shaft. There are no elements to wear or break under normal usage. Sealed to retain oil, it is dust-proof and moisture-proof.

A small quantity of a few sizes now carried in stock—rough bored—await your order, subject to prior sale. Write for quotations. For complete description, send for a copy of Catalog No. 443.

FARREL-BIRMINGHAM COMPANY, INC.
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Plants: Ansonia and Derby, Conn., Buffalo, N. Y.
Sales Offices: Ansonia, Buffalo, New York, Pittsburgh, Akron, Los Angeles, Tulsa, Houston

Here is shown the extreme range of sizes of the Farrel Gearflex Coupling—the huge 20" with the little 2" on top.

FARREL GEARFLEX COUPLINGS Sizes, Ratings, Bores

Size No.	Capacity HP per 100 RPM	Maximum Bore in Inches	Rough Stock Bore—Inches	
			One Half	Other Half
2	23	2	1	1
2 1/2	45	2 5/8	1 1/4	1 1/4
3	80	3 3/16	1 1/2	1 1/2
3 1/2	120	3 11/16	2	2
4	180	4 1/4	2 1/2	2 1/2
4 1/2	250	4 3/4	3	3
5	350	5 1/4	4	3
6	500	6 3/8	5	3 1/2
7	800	7 1/2	6	4
8	1200	8 1/2	7	5
9	1800	9 1/2	8	6
10	2400	10 3/4	9	7
11	3200	11 3/4	10	8
12	4000	12 3/4	11	9
14	6300	15	13	11
16	9100	17	15	13
18	12000	19	17	15
20	19000	21	19	17

FARREL

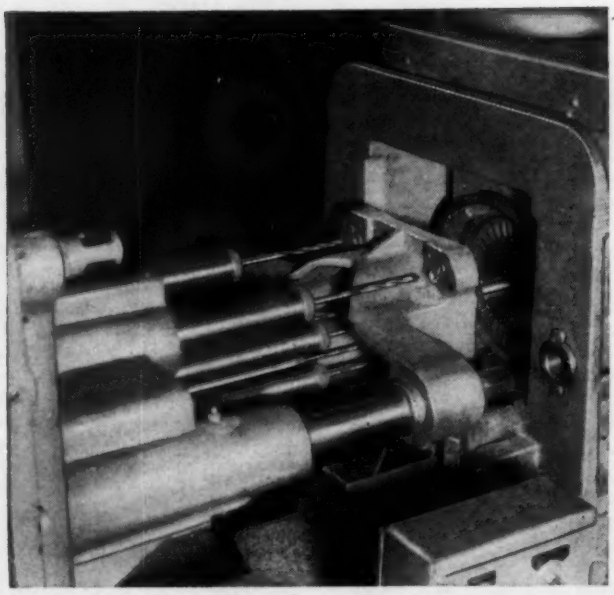
farrel-Birmingham

BLESSED BOLT HOLES

It's a blessing to electricians and maintenance men when bolt holes in motor end shields and frames are exactly in line, and mounting holes in the feet are uniformly and accurately positioned. Installation is easier. Interchanging of motors, rotating of end shields, and reversal of stators are all more quickly accomplished. Tight fits are obtained without forcing. Bearing alignment is insured, internal strains are avoided. During the war period, jig-fixture uniformity maintained in machining, drilling, and tapping Tri-Clad motor frames has saved thousands of man-hours of installation and servicing.

End shields are easily rotated for inverted motor mounting.

JIGS AND FIXTURES OF ADVANCED DESIGN MEAN CLOSE FITS IN TRI CLAD MOTORS



Frame-drilling operation at G.E.'s Lynn (Mass.) Works.

Specially built production equipment, as well as test apparatus, helps build Tri-Clad motors with close fits and clearances. Here, all bolt holes in the frame are drilled in a single operation within a rigid fixture that insures accurate positioning. In the finished motor, this results in more accurate shaft alignment, smoother operation, longer bearing life. General Electric's high-volume motor production permits tooling up for high precision without increasing the cost to you. *General Electric Co., Schenectady 5, N.Y.*

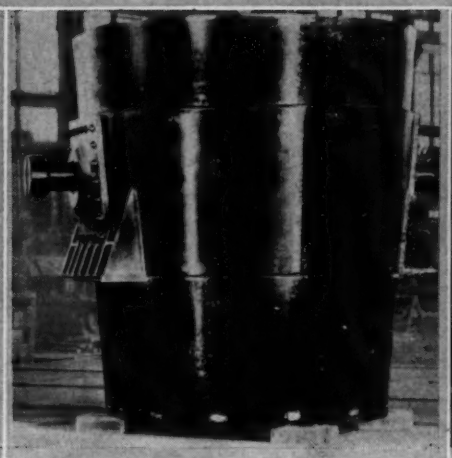
GENERAL ELECTRIC

Buy all the BONDS you can—*and keep all you buy.*

ENGLISH REPRESENTATIVE: INTERNATIONAL CONSTRUCTION CO., 56 KINGSWAY, LONDON, W.C. 2, ENGLAND

HOW WELDING AND CUTTING METHODS ARE AIDING MILL MAINTENANCE . . .

Building up worn areas of a feedwater pump casing by bronze welding. Airco No. 100 bronze electrode is highly recommended for applications of this kind.



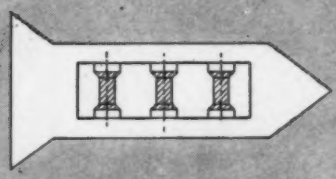
This 85 ton ladle was shop-fabricated as a needed replacement by standard welding and flame cutting methods. It is 20% lighter than riveted ladles, and has greater load capacity.

Salvage as well as maintenance is aided by flame methods. Here an Airco oxygen lance is used to break up a large open-hearth furnace spill for remelting.

THESE are only a few of the ways in which modern welding and cutting methods—and Airco quality materials—are providing important aid in wartime mill maintenance. In view of the continuing scarcity of new and replacement parts, every steel mill maintenance man will want to use these versatile and economical methods wherever possible. Your nearest Air Reduction office will gladly send a representative to consult with you on your special maintenance and repair problems. Call or write today for full details.

If you would like to receive free copies of an interesting booklet "Welding Aids Mill Maintenance", write to Dept. IS, at the New York office.

Shear blades of 45 to 50 carbon steel are made to outlast ordinary shears by hard-surfacing one cutting edge (shaded area) with Stoody No. 6, an alloy which retains high hardness even at red heat.



Roller guides hardfaced with Stoody No. 6 alloy (on the shaded areas) give more than double the length of service of guides not similarly treated.

Sulphate scraper blades of this type used in by-product coke plants are made to last three times as long as untreated blades by applying a thin coat of Stoody hard facing alloy.

★ BUY UNITED STATES WAR BONDS ★

"FIGHT INFANTILE PARALYSIS JANUARY 14th — JANUARY 31st"

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The number of years any concern has behind it means little if each of those years hasn't marked further progress and improvement of its products . . . Our relations with the Steel and Non-Ferrous Industries for the past three-quarters of a century give ample proof that we have made good use of this time.

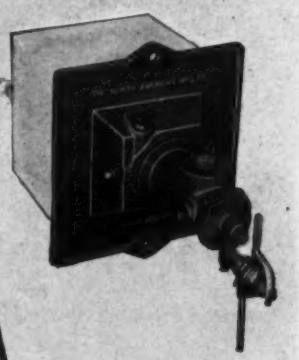
PITTSBURGH ROLLS

Division of Blaw-Knox Company
Pittsburgh, Pa.

Pioneered by North American

LUMINOUS OR LONG FLAMES with either gas or oil are produced by the Series 113 Burners. They are desirable for vast coverage, for fewer burners and for uniformity of flame temperature.

SHORT FLAMES are produced by the Series 221 Burners. These burners provide a highly stable and efficient fire, using either gas or oil. They are recommended wherever heating in a relatively small space is required.



WRITE FOR DESCRIPTIVE LITERATURE

DUAL-FUEL BURNING SYSTEMS FOR GAS AND OIL

MAXIMUM EFFICIENCY WITH EITHER FUEL—designed especially for gas and for oil.

SWITCH FUELS INSTANTLY—no change required in piping or burner inserts.

AUTOMATIC FUEL-AIR PROPORTIONING—one air valve controls the fire of one or a battery of burners regardless of the fuel being burned.

WIDE TURNDOWN RANGE—no "flash back" possible.

●

THE NORTH AMERICAN MANUFACTURING COMPANY
MANUFACTURERS OF INDUSTRIAL FUEL BURNING EQUIPMENT FOR GAS OR OIL
BRANCH OFFICES AND FIELD ENGINEERS IN PRINCIPAL CITIES
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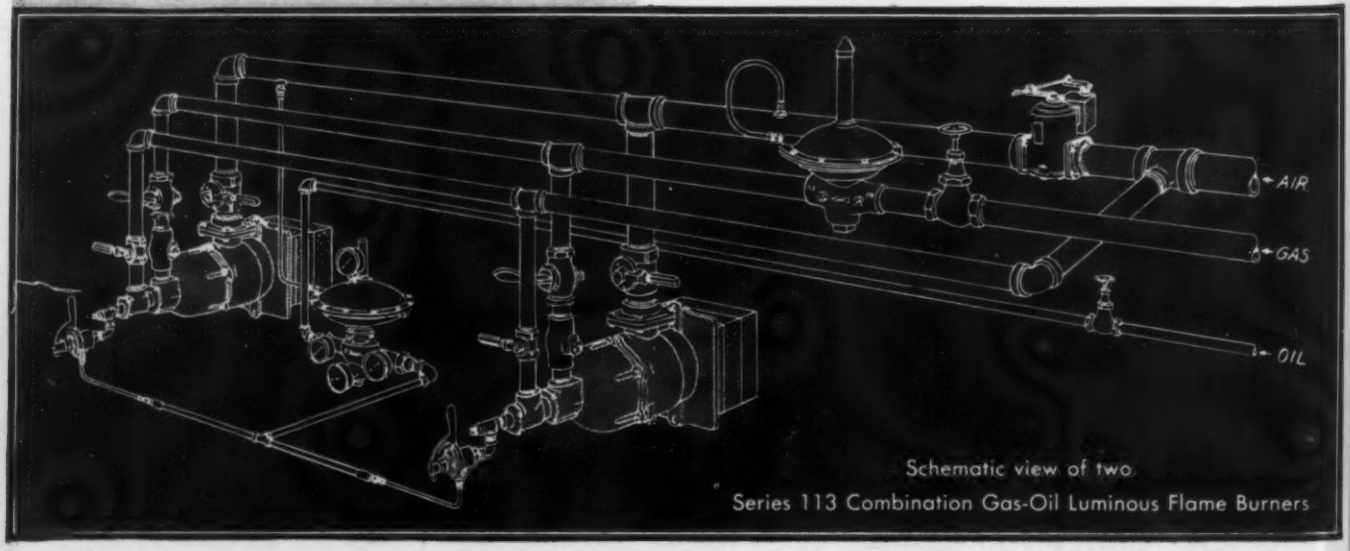
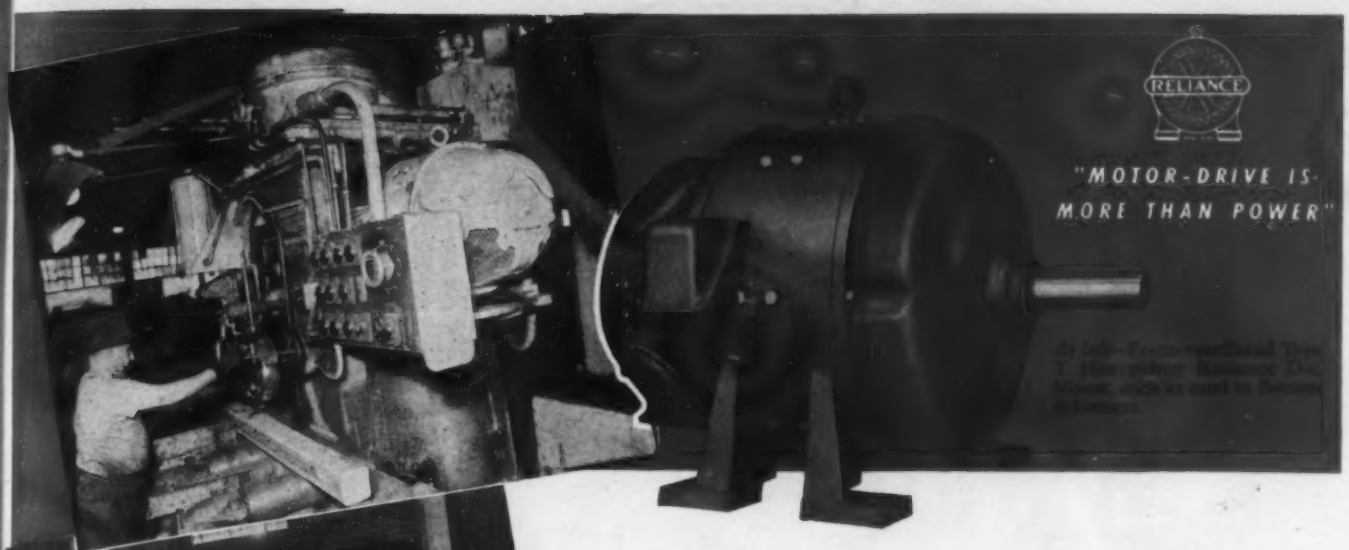
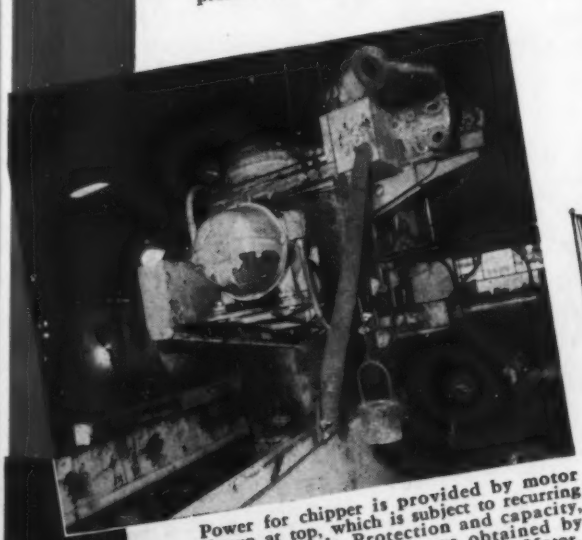


Schematic view of two
Series 113 Combination Gas-Oil Luminous Flame Burners



Seven Reliance Motors provide power for the various operations of the Bonnot Billeteer shown in top illustration. All motors are controlled from one station.

Billets are started on their way by the Reliance Motor in right foreground of picture just above.



Power for chipper is provided by motor shown at top, which is subject to recurring shock overloads. Protection and capacity without excess weight are obtained by a force-ventilated enclosed Reliance Motor.

CLEAN BILLETS *at 20 TIMES THE SPEED OF HAND CHIPPING*

Bonnot Billeteers in leading steel plants are realizing the full advantages of Reliance Motor-drive by delivering clean billets at 20 times the speed of hand chipping. Equally important is the fact that this is being done faster and at a lower cost than by any other method.

The Bonnot Billeteer is a good example of modern production machinery in the steel industry, calling for a wide diversity of motor applications. The efficiency with which this machine performs its various functions demonstrates the many things which may be accomplished through proper application of electric motor-drive.

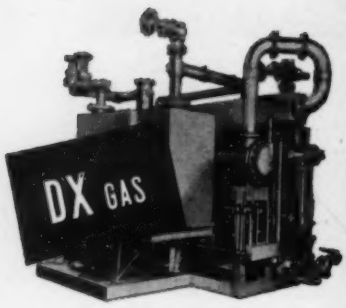
A talk with a Reliance Application Engineer about this and other Reliance installations will prove to your satisfaction that Motor-Drive Is More Than Power.

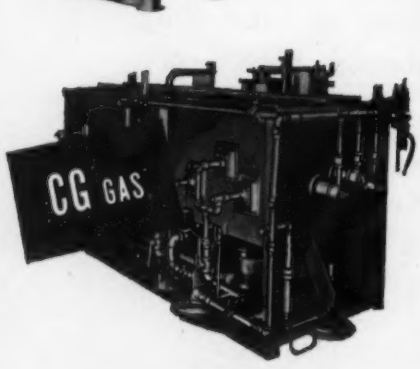
RELIANCE ELECTRIC & ENGINEERING CO.

1088 Ivanhoe Road • Cleveland 10, Ohio

Birmingham • Boston • Buffalo • Chicago • Cincinnati • Detroit • Greenville (S. C.) Houston • Kalamazoo • Los Angeles • Minneapolis • New York • Philadelphia • Pittsburgh Portland (Ore.) • St. Louis • San Francisco • Syracuse • Washington, D.C. • and other principal cities

RELIANCE A-C D-C MOTORS





The (SC) Primer of

PREPARED ATMOSPHERES

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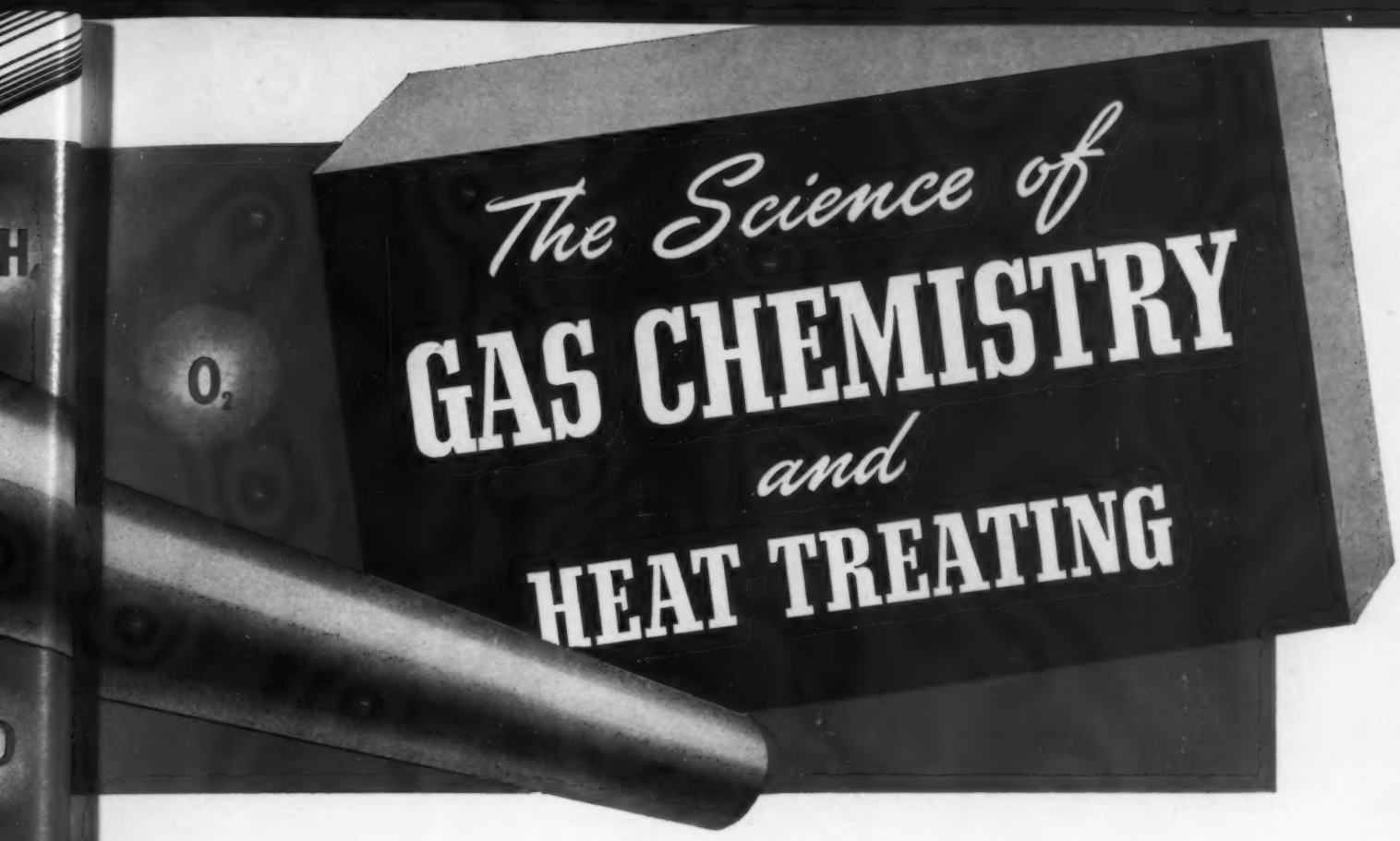
A booklet that compresses into handy form the information that every steel mill heater should have at his finger tips. Write for your copy today.



The Science of GAS CHEMISTRY and HEAT TREATING

Surface Combustion research in the use of gases for atmospheres in the heat treatment of metals, has made possible metallurgical results of such significance that it goes far beyond the mechanical details of furnace construction.

Today, with the use of Surface Combustion Radiant-Tube Heating Elements and Prepared Atmosphere Generating Units metal surfaces are preserved, including both high and low carbon steels and non-ferrous metals. There are atmospheres to prevent decarburization of steels, and also for recarburization in case the carbon has been removed by an earlier operation. There are surface hardening atmospheres of a number of kinds, and atmospheres for producing specific effects upon metal surfaces.

In addition to these surface treatments, recent developments have shown marked effects of small amounts of gases within the physical structure of metals. Some of these gases are retained from the melting operation and some are entrapped during heat treatment. Some gases cling tenaciously to a metal surface just short of chemical union, while others are readily driven off into the surrounding medium. It is desirable to eliminate harmful reactions between metals and gases, and to develop superior metallurgical properties here-to-fore unknown. Gas quenching and dry pickling are recent outstanding Surface developments embracing the science of gas chemistry and heat treating, that have been industry proven. Other major developments are in the making.

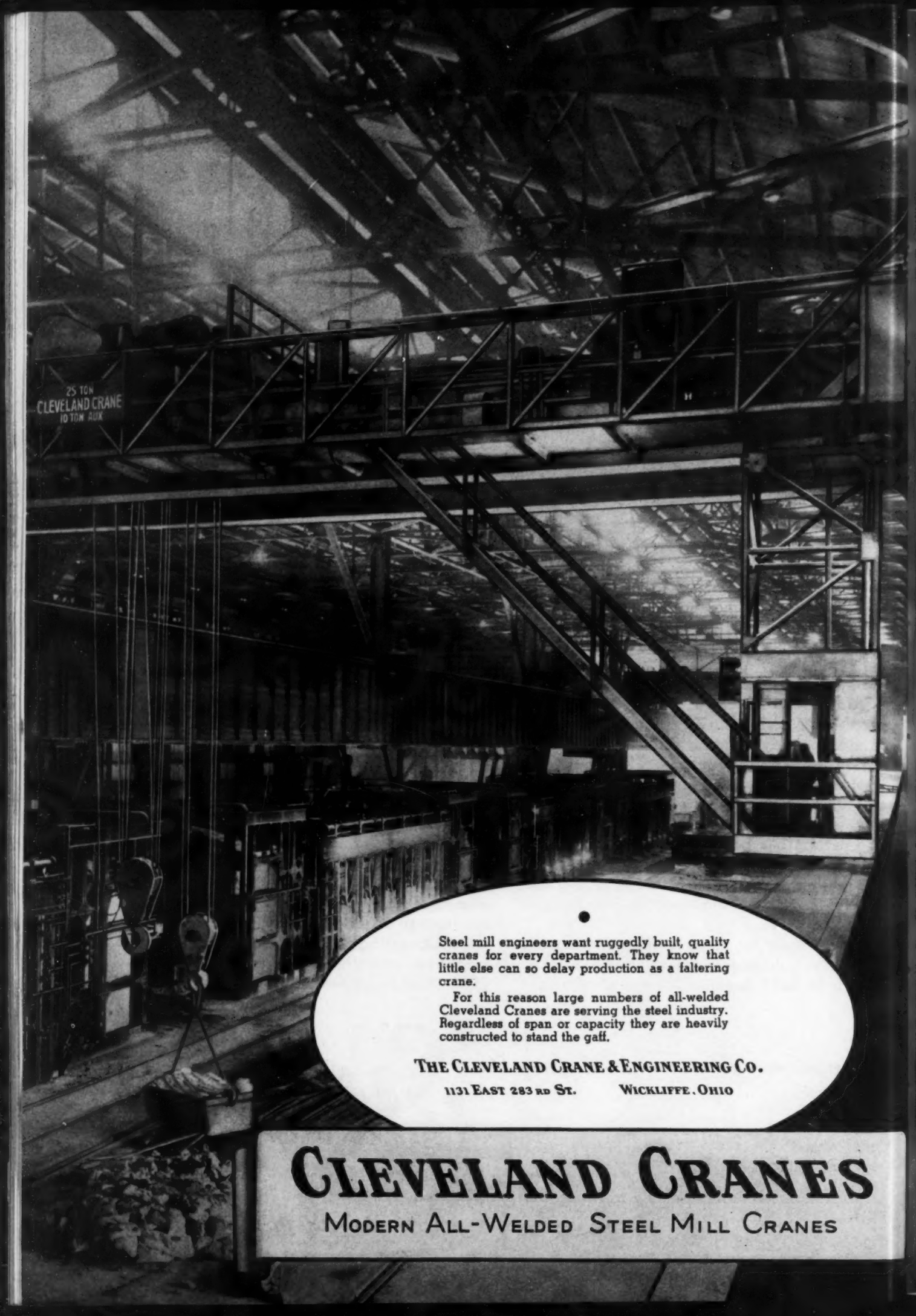
Surface believes that great advancements in metallurgical treatment will come from the application of gas chemistry...that many post-war heat treating problems will be approached from new scientific angles that will give superior results at new low production costs.

The Heater's and Heat Treater's Helping Hand

'Surface'

SURFACE COMBUSTION • TOLEDO 1, OHIO

WHEREVER HEAT IS USED IN INDUSTRY
...FROM INGOT TO FINISHED PRODUCT



Steel mill engineers want ruggedly built, quality cranes for every department. They know that little else can so delay production as a faltering crane.

For this reason large numbers of all-welded Cleveland Cranes are serving the steel industry. Regardless of span or capacity they are heavily constructed to stand the gaff.

THE CLEVELAND CRANE & ENGINEERING CO.

1131 EAST 283 RD ST. WICKLIFFE, OHIO

CLEVELAND CRANES

MODERN ALL-WELDED STEEL MILL CRANES

Crops *and* Shorts

ALTHOUGH the German counter-offensive has caused many casualties and has disrupted our plans, perhaps it was necessary to shake us loose from our growing over-confidence. One thing sure, Von Rundstedt seems to have put the quietus on talk of early conversion and civilian production.

▲

TWO salvage drives — for tin and waste paper — must be intensively carried on for some time. The drives for used fats and for old rags must also continue, although these items have become somewhat less critical. All indications at present, however, point to 1945 as a year of shortages, and WPB has issued many new orders and amendments designed to further conserve tin, lead, carbon steel scrap and many other items.

▲

AT least $100,000,000 has been already added to the cost of the war by differing standards — screw threads is one example — according to William L. Batt.

▲

A RECENTLY printed pamphlet, "The Revolution Was," written by Garet Garrett and published by The Caxton Printers, Ltd., Caldwell, Idaho, should be required reading for every citizen of the United States who believes and desires a free system of competitive, private enterprise.

▲

BITUMINOUS coal production for 1944 approximated 622,000,000 tons, 37,000,000 tons above the 1943 record, and accomplished with a reduced labor force.

▲

PAYROLLS in the steel industry reached $1,700,000,000 in 1944, according to Walter S. Tower, president of the American Iron and Steel Institute. And despite record production, net earnings of the steel companies are expected to total approximately $170,000,000, about 20 per cent under 1943 profits.

▲

IT is estimated that absenteeism in munitions industries, excluding sick leave, paid vacations and strikes, will total 115,000,000 man-days during 1944, or more than eleven days per worker.

▲

PERHAPS the testimonial on a recent radio program plugging soap, wherein a man was quoted as saying "I stoke a blast furnace at Weirton Steel," is a tip on a new process.

▲

IF you add 10,980,000 automobiles, 10,500,000 refrigerators, 6,042,000 washing machines, 6,351,000 vacuum cleaners, 16,755,000 electric irons, 7,923,000 toasters, 41,000,000 radios, 82,380,000 clocks and watches, 10,400,000 furnaces and heaters, 14,010,000 stoves and ranges, you have quite a bill of goods — but that is OPA's estimate of some civilian needs at the end of 1944. The automobile industry feels that it can build 6,000,000 new cars in the first 12 months of unrestricted production, and 25,000,000 in the first 5 years.

▲

A SURVEY made by the Coordinator of Inter-American Affairs indicates that post war expansion of Mexican industry will open a $986,000,000 market for machinery and equipment from the United States.

▲

ACCORDING to a Bureau of Mines report, forcing gas and air into underground oil reservoirs (one method of secondary petroleum recovery) has brought a 30 per cent increase in production from some of the wells in Illinois fields from which most of the oil obtainable by primary methods has been extracted.

▲

IT is when we forget ourselves that we do things for which we are remembered.

▲

MARKETED production of natural gas in 1943 was 3,414,689,000,000 cu ft, 12 per cent above the 1942 figure. This was used by 10,353,870 domestic and 811,090 commercial consumers.

▲

BRASS strip is reported to be a "must" item in quantities exceeding brass mill capacity by about 15 per cent, and the steel industry may again be called on to plug the gap.

▲

ACCORDING to estimates made by F. W. Dodge Corporation, construction activity in the United States during the first 12 months after the day when most controls on materials and manpower are relaxed will probably approximate that of 1938, which was more than 50 per cent above 1944.

▲

DURING 1944 the airdraft industry brought its production to a peak monthly rate equivalent to 100,000 planes per year. It is estimated that this is 5 times the German production rate and nearly 8 times that of the Japanese.

ONE OF *America's Biggest*

is 100%

ON HOT AND COLD MILL

Wherever there's a bearing on hot and cold mill work and back-up roll necks and on drives, cranes, tables, coilers, etc., of this huge installation, there's an SKF Spherical Roller Bearing.

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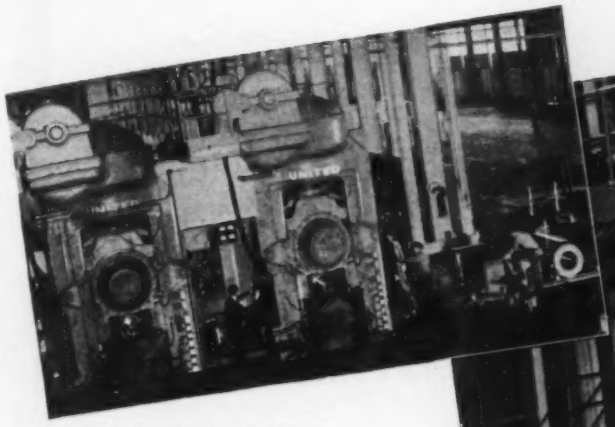

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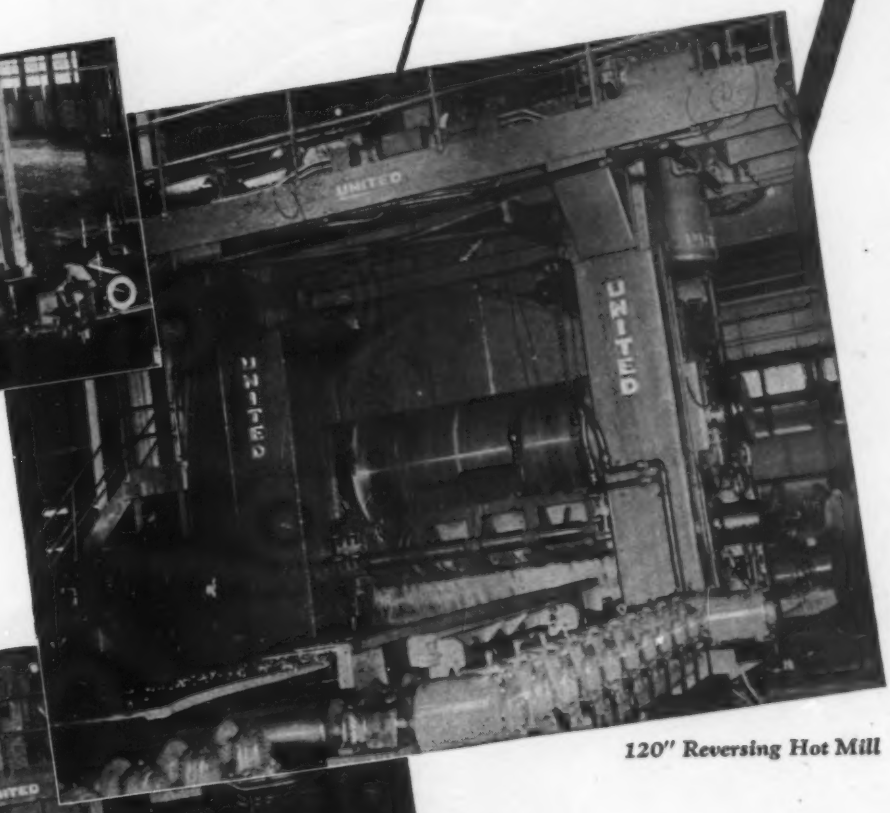

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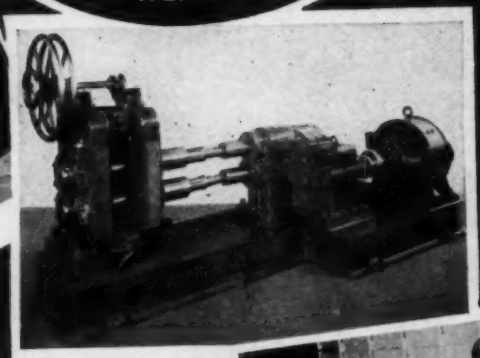

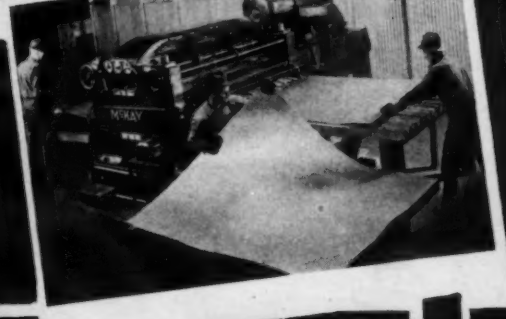

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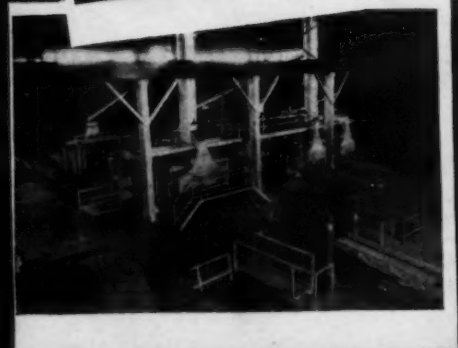

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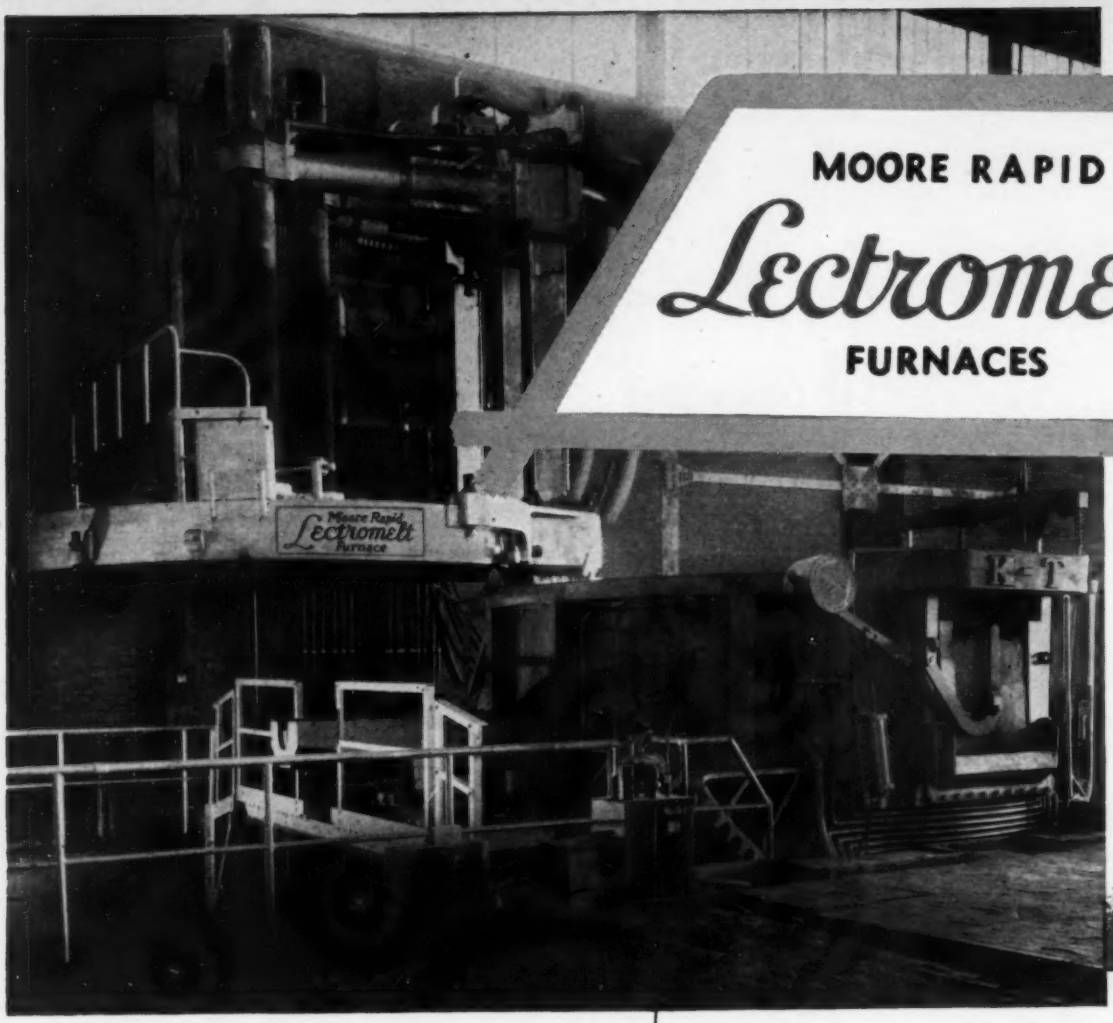


MOORE RAPID Lectromelt FURNACES

A size "KT" Lectromelt top charge furnace with roof rotated, ready to be charged by a drop bottom charging bucket. This is one of the heavy, steel mill type furnaces.

★Moore Rapid Lectromelt Furnaces are built in a wide range of standard sizes from 100 tons down to 25 pounds capacity. Almost all of the Lectromelt furnaces installed during the past few years have been of the top charge type. The top charge feature offers many advantages such as greater output due to decreased charging time, lower power and refractory costs, increased production per man hour and many others. Especially large pieces of scrap can be charged readily, and light fluffy scrap can be charged to shell height with a drop bottom bucket. In some of the very large sizes—frequently arranged for installation on an open-hearth platform—a door charge furnace may be used with the charging being handled by an open-hearth charging machine.

The following tables list some pertinent data on the various sizes of Lectromelt Furnaces:

TABLE I. These larger capacity furnaces are of the heavy, steel mill type and are generally used for ingot production.

Lectromelt Size	Nominal Size of Heat	Shell Diameter	Nominal Capacity of Substation
HT	75-100 Tons	20'—0"	15,000 kva
IT	60-75 Tons	19'—0"	15,000 kva
JT	50-60 Tons	18'—0"	12,000-15,000 kva
KT	40-50 Tons	17'—0"	10,000-12,000 kva
LT	30-40 Tons	16'—0"	8,750-10,000 kva
MT	25-30 Tons	15'—0"	7,500 - 9,375 kva
NT	15-20 Tons	12'—4"	7,500 - 9,375 kva
OT	8-12 Tons	11'—0"	6,000 - 7,500 kva

TABLE II. The Lectromelt furnaces listed in this table are generally used in foundry work but many of these smaller furnaces are used in ingot shops for pouring billet size ingots or for tool steel.

Lectromelt Size	Usual Hourly Production Rate*	Usual Size of Heat**	Nominal Size of Substation
OPT	4½ Tons	8-9 Tons	3,000-3,750 kva
PT	3 Tons	5-6 Tons	2,000-2,500 kva
CQT	2 Tons	3½-4 Tons	1,000-2,000 kva
QT	1½ Tons	2½-3 Tons	1,200-1,500 kva
RT	1 Ton	2 Tons	800-1,000 kva
ST	1,000 Pounds	1 Ton	400- 500 kva
TT	500 Pounds	1,000 Pounds	300- 375 kva
UT	250 Pounds	500 Pounds	200- 250 kva

*On acid practice or single slag basic practice.
**The furnaces are so constructed that, when the occasion demands, especially large heats can be poured, considerably in excess of the "usual" heats listed.

TABLE III. The Lectromelt furnaces listed in this table are intended primarily for laboratory and experimental use. These furnaces are for operation from a single phase supply.

Lectromelt Laboratory Sizes	Usual Size of Heat	KVA Rating
V	200-300 Pounds	100
VW	100 Pounds	100
W	50 Pounds	50
X	25 Pounds	37.5

PITTSBURGH LECTROMELT FURNACE CORPORATION
PITTSBURGH 30, PENNSYLVANIA

THE *Uni-Temper Mill* AND *Process*

. . . . two years of operating experience on the first installation of this new mill design have borne out the results of experimental investigations . . . . the product has definitely different characteristics, while operating economy has been attractive . . . .

by M. D. STONE, MANAGER
DEVELOPMENT DEPARTMENT
UNITED ENGINEERING AND FOUNDRY COMPANY
PITTSBURGH, PENNSYLVANIA

▲ IN the manufacture of most cold-reduced strip for such purposes as tin plate, auto-body sheets, furniture stock, stainless steel panels, etc., a necessary production step is the temper rolling or skin rolling operation. Its usual position in the production cycle is after the sequence of hot rolling, pickling, cold reducing and annealing, and its purpose is to produce a flat strip of specified gauge, hardness or temper, drawability, etc.

In the manufacture of tin plate, for example, because of the thinness of strip used — from .007 in. to .011 in. — and the large amount of cold reduction involved — from, say, .078 in. to .010 in. (80 to 90 per cent) — it is necessary that the cold rolling be carried out with the use of rolling oils to maintain rolling pressures and powers at reasonable values. Then, since no oil may be tolerated on the final product on account of staining and interference with proper tinning (either hot dip or electrolytic), an electrolytic cleaning operation is resorted to, prior to annealing. It is therefore evident that the temper rolling itself must be carried out dry, i.e., without benefit of rolling oils or coolants, to avoid the necessity for another cleaning operation.

As a consequence, even though the reductions involved are only of the order of from 2 to 5 per cent (sometimes as high as 10 per cent for extreme tempers) it is impractical to take such a reduction in a single pass through even a heavy duty 4-high temper mill. In the tin can industry there is a customary range of "tempers," from T-1 to T-6, and sometimes higher for special cases. In Figure 1 are shown the usual ranges of hardnesses corresponding to those tempers and the corresponding number of passes usually required by conventional 4-high mills. The several tin plate producers modify this practice somewhat to fit plant conditions. In some cases, to get the higher hardnesses and to permit less reduction on the mills, the chemistry of the steel is modified from the usual "rimming steel" specifications to rephosphorized bessemer, and even to dead-killed steels.

In following either of the above procedures, i.e., multi-stand rolling or utilizing special chemistry steel, considerable cost is involved. In the latter case, the cost arises from the necessity of processing different steels and stocking them, rather than from any inherent cost differences themselves. In either case, the rolling mills involved are of heavy 4-high construction. Both the rolling pressure, as measured in pounds per inch of width, and the rolling power, as indicated by hp-hr per ton, are higher in the usual temper rolling operation than in either hot rolling or cold rolling for comparable reductions, and as a rule despite far greater reductions.

Presented before A. I. S. E. ANNUAL CONVENTION, Pittsburgh, Pa., Sept. 25-27, 1944

TEMPER No.	HARDNESS No. (ROCK. B)	USUAL NUMBER OF MILL PASSES
T-1	46/52	1
T-2	48/54	1
T-3	54/60	1
T-4	58/64	2
T-5	62/68	2 To 3
T-6	64/70	3

Figure 1 — Usual relations between temper numbers, hardness numbers and mill passes.

As round average figures — cutting across all variations in rolling practice as to temperatures, speeds, tensions, roll sizes, lubricants, etc. — hot mill practice involves pressures of from 45,000 to 60,000 lb per inch of width, and cold strip mill practice ranges from 60,000 to 80,000 lb per inch of width. Temper mill practice, while considerably lower for heavier gauges and lighter reductions, ranges from 65,000 to 90,000 lb per inch of width for tin plate gauges, and in some cases has exceeded 100,000 lb per inch.

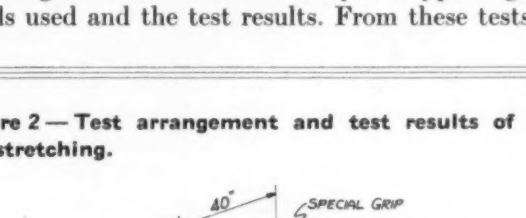
As to rolling power or energy, the energy per ton in a usual hot strip mill reducing mild steel from, say 6 in. to .060 in., corresponding to an average reduction of 99 per cent, will vary between 50 and 70 hp-hr per ton, with a possible maximum of around 10 hp-hr per ton per pass, say on F-7, taking about a 35 per cent reduction. For cold reduction from 0.078 in. to 0.010 in. (87 per cent), the overall energy consumption will vary from 100 to 120 hp-hr per ton, with a possible maximum on perhaps the third or fourth pass of about 40 hp-hr per ton per pass when taking around a 40 per cent reduction. For temper rolling, for example from 0.0100 in. to 0.0095 in. (overall reduction of 5 per cent), the total energy consumption will vary around 15 hp-hr per ton and higher, requiring two passes. From the above it is seen that, per mill, hot rolling requires about ⅓ hp-hr per ton for each 1 per cent of reduction; cold rolling about 1 hp-hr per ton for each 1 per cent of reduction; and in temper rolling the figure is as high as 3 hp-hr per ton for each 1 per cent of reduction. It is thus obvious that the temper rolling operation has been the most difficult strip-rolling operation with which we have had to deal.

Prior to the war an investigation as to the possibilities of performing the tempering operation by tension-stretching the strip, as contrasted to rolling, was initiated. A great deal of skepticism had to be met, particularly as to the possibility of tensioning strip at high speed and at stresses above the yield point without tearing the strip frequently and so making nothing but scrap.

The first step was to study more thoroughly the phenomena associated with stretching above the yield point of wide, thin sheet. General information was available, of course, on the stress-strain relations and accompanying cold work characteristics of low carbon steel, as is provided by the conventional tension test pieces. And there was also some information available on the behavior of sheets as stretched for flattening purposes in the well known stretcher leveler. Nevertheless, a series of tests was carried out in which sheets were stretched to varying degrees, from ½ per cent to 20 per cent, with varying thicknesses, varying widths, varying stretch lengths, varying pretreatments (such as roller leveling, prerolling, etc.) and various post-treatments. The sheets thus stretched were investigated for grain structure, longitudinal vs. lateral mechanical properties, relation of hardness to ductility, aging (accelerated, as takes place in hot-dip tinning), nature of surface (as it might influence subsequent electroplating or coating techniques), flatness, etc. Possibly most important of all, tin cans — both sides and tops — were made from these sheets. The results of these preliminary tests were extremely interesting and promising, and opened up new avenues of thought and development.

In order to determine the behavior of the sheets being stretched, a special gripper was made to be fitted into one jaw of a conventional stretcher leveler (96 in. span) to enable spans of as little as 6 in. to be obtained. The most detailed series of tests was made on dead-soft tin plate stock .010 in. thick in widths of 6, 12, 24 and 32 in., varying the spans to obtain 6, 12, 24, and 36 in. in each case. Figure 2 shows schematically the type of gripper heads used and the test results. From these tests it is

Figure 2 — Test arrangement and test results of sheet stretching.



SHEET WIDTH	STRETCH SPAN	ELONGATION	WIDTH REDUCTION	TYPE OF FAILURE
32"	36"	10.6 %	—	GUTTERED
	24"	9.8	2.7 %	NO GUTTERING TORE IN GRIP
	12"	11.1	1.7	" "
	6"	17.5	1.1	" "
24"	36"	6.3	—	GUTTERED
	24"	11.6	—	"
	12"	11.3	2.8	NO GUTTERING TORE IN GRIPS
	6"	15.0	2.6	" "
12"	36"	15.2	—	GUTTERED
	24"	20.6	—	"
	12"	13.1	—	" (AFTER 10%)
	6"	17.5	4.7	NO GUTTERING TORE IN GRIPS
6"	36"	3.8	—	GUTTERED
	24"	5.3	—	"
	12"	10.0	—	"
	6"	17.5	7.3	NO GUTTERING TORE IN GRIPS

DEAD SOFT TIN PLATE STOCK .010" THICK

seen that a rough rule may be established — that as long as the stretch span remained shorter than ⅔ of the width, "guttering" did not take place. For material that was thicker, or prerolled (even ¼ per cent) or roller leveled, greater spans could be used without failure. It was noted, however, that where the sheets did not gutter, they usually failed in the grips at elongations in some cases as low as 9.5 per cent and in other cases as high as 20 per cent, but it was realized that these grips, particularly the fixed grip, were poorly designed from the point of view of preventing local failure, due to deeply knurled gripper heads to prevent slipping, etc.

This phenomenon of "guttering" is one of considerable interest, and a complete series of tests is under way to study its incidence as a function of sheet thickness and other dimensions, type of material, etc. It might well be characterized as "tensional buckling," in that laterial instability sets in under longitudinal tension stresses when such stresses exceed the yield point by certain amounts.

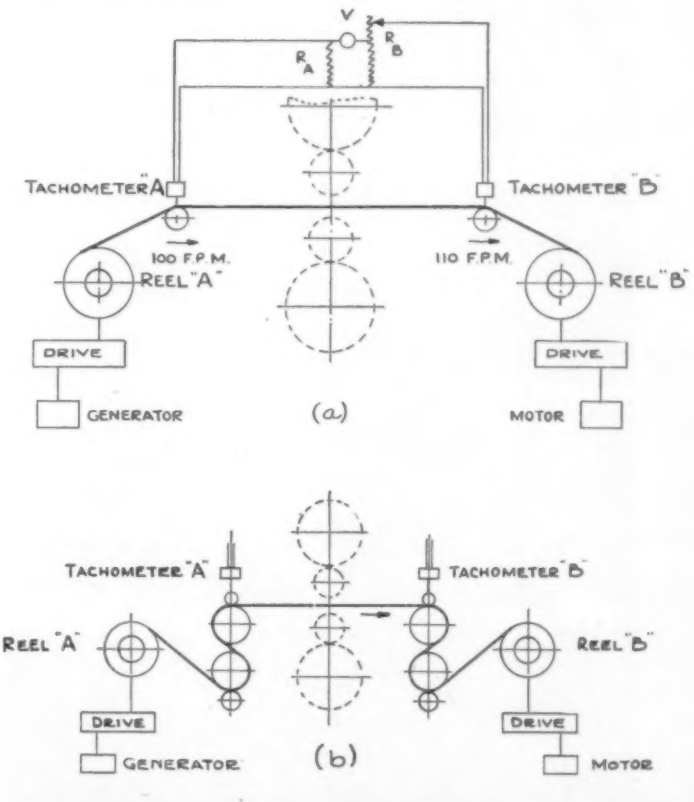
Contemporaneous with these earlier sheet tests, experiments were planned and carried out to evaluate the feasability of continuous stretching. Two types of equipment were tried: an uncoiler and reel combination (by dummying through a mill), and an uncoiler-entry tension unit pulling against a reel-delivery tension unit (also dummying through a mill), as shown in Figure 3. Generator-type tachometers were connected to the uncoiler and reel billy rolls in the first case, and to the tension-unit top rolls in the second case. Many coils were run through at speeds of 100 to 200 fpm with surprising ease, even though the control of speed differential was entirely manual. In anticipation of strip tearing, initial coils were side-trimmed, but immediately thereafter, side-trimming was discontinued, as rolled edge coils showed no special tendency to tear except where definite edge cracks were present to begin with. In order to assist in producing coils with essentially constant elongation, a differential voltage system was used, as shown in Figure 3a. By presetting resistance R_B, say, 10 per cent greater than R_A, the speed of the delivery reel B was increased, while entry reel A was delivering power back into the power system, till the voltmeter shown read zero. At this point, we knew we were stretching the strip exactly 10 per cent. Our surprise was great in finding how easy it was to do this.

These experiments showed that the long span over which the strip was being stretched caused guttering and ultimate creases in the steel, which tendency was somewhat mitigated by interposing intermediate deflector rolls. They showed, as well, that under such conditions the strip decreased considerably in width as well as thickness — something that was naturally expected. However, in the arrangement (a), for an elongation of 10 per cent, the widths decreased by almost 4 per cent (say 1⅛ in. in 28 in.), whereas in case (b), where the strip was restrained laterally to a greater extent at each end of the stretch length, the decrease in width was considerably less, but still present. In each case the decrease in width took place gradually over the stretch length, forming a sort of wedge shaped strip. In those cases where dead-soft annealed coils were used, stretcher strains were very apparent in the coiled strip, with slightly remanent effects still visible even for the higher elongations. This latter condition was, to some extent unexpected, based on some laboratory tests that were made on a standard tension testing machine.

Several strips of tin plate about 2 in. wide and about 10 in. long in three conditions (a) as annealed; (b) annealed and roller leveled; and (c) annealed and temper rolled 6 per cent were pulled varying amounts ranging from ¼ per cent to 12 per cent. These are shown in Figures 4, 5 and 6. In the case of temper rolled material there was no evidence at any stage of any surface distress, only an almost imperceptible roughening up taking place. The roller-leveled sheets were not quite so free of surface deformations, which were more apparent at the lower elongations, but disappeared as stretching progressed. The annealed sheets, however, showed the now well known stretcher strains or "Luders lines" — but only for the lower elongations. By continued stretching, these distress patterns were entirely eliminated, leaving only a rougher surface still uniform in appearance.

This phenomenon of "pulling through the yield point elongation" was touched upon by Winlock [1, 2] in discussing various aspects of stretcher strains as they affect the deep drawing qualities of automobile body sheet. In tracking down this matter, it was found that the faster the strip was stretched, the greater the yield point elongation, as illustrated in Figure 7. Two tests were made at widely different speeds, one at .0046 in. per minute velocity of the movable head (corresponding to .002 in. per minute, or 1/5 of 1 per cent per minute rate of strain — about a 2.3 in. stretch length), and the other at 2200 times this speed (at 10.1 in. per minute, or 440 per cent per minute). In the first case, the yield

Figure 3 — Types of continuous tensioning mills used in preliminary tests.



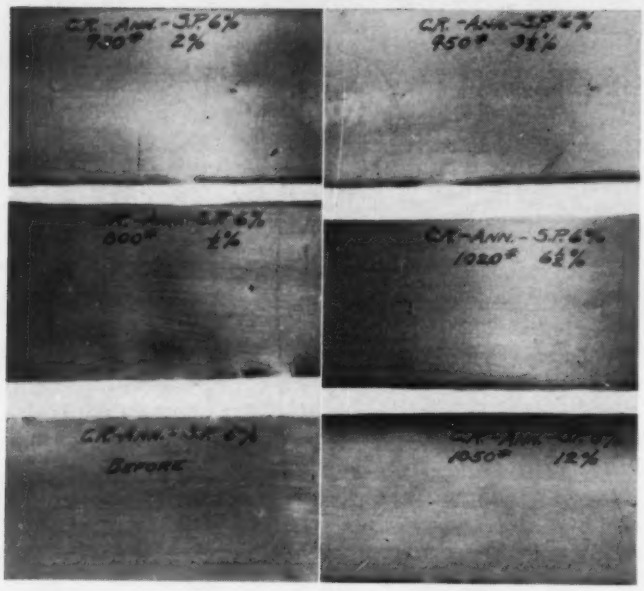


Figure 4 — Surface conditions at various stages in tensioned strip previously temper rolled 6 per cent. (above)

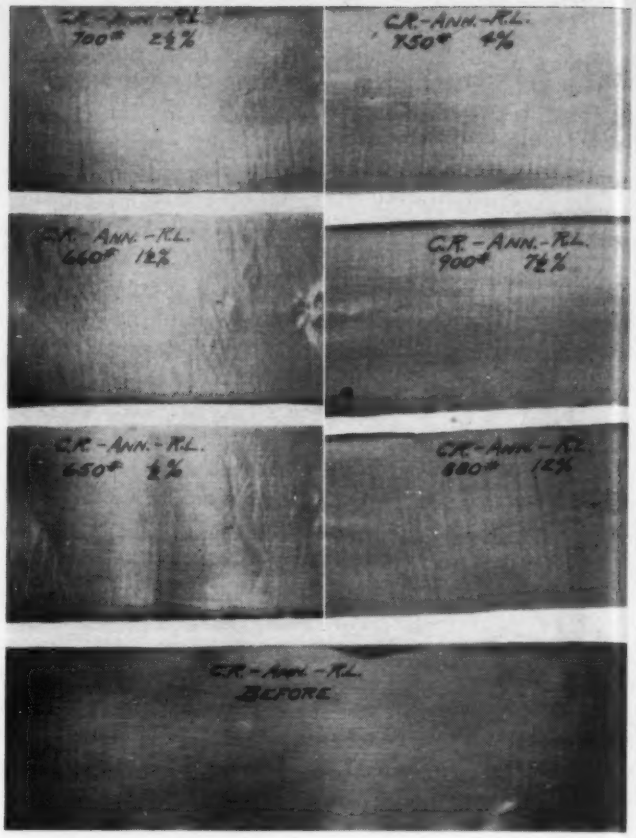
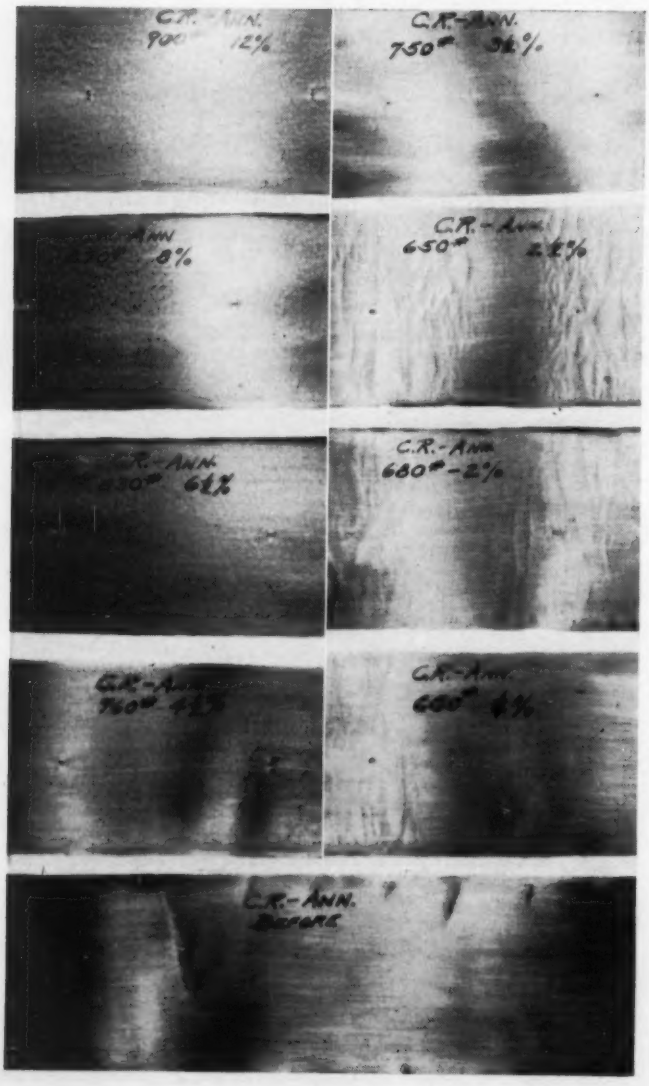


Figure 5 — Surface conditions at various stages in tensioned strip previously roller leveled. (above right)

Figure 6 — Surface conditions at various stages in tensioned strip which was dead soft annealed. (below)

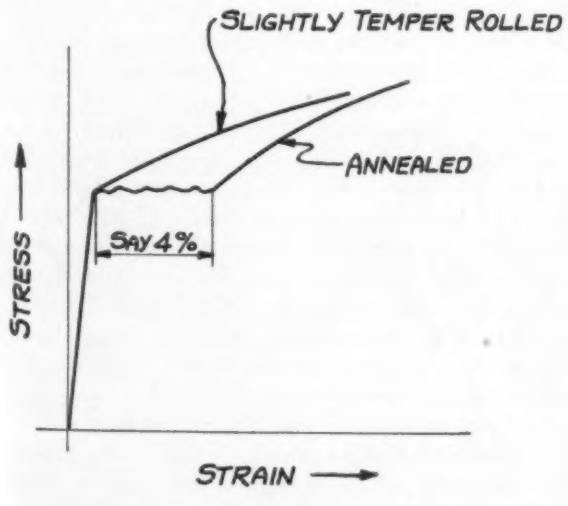


point elongation was 3 per cent and in the second, 13 per cent. It is clear, therefore, that if the desired physical properties required an elongation of 5 per cent, the stretcher strains would disappear if the elongation were carried out slowly, but would remain if elongation were carried out rapidly. Of course it is appreciated as well that the physical properties in the two cases would conceivably be different. It is to be noted also that the yield point is far greater at the higher rates of stretching, whereas the ultimate stress and total elongation are little affected. A possible explanation of this interrelation of increased yield point stress, keeping ultimate stress and total elongation constant, is indicated in Figure 7(b). Now, in uni-tempering, even at speeds as low as 200 fpm and for elongations of 5 per cent, the rate of strain exceeds 10 per cent per second, so that it became evident early in the development and design of the mill that other means of eliminating stretcher strains or preventing them from occurring were necessary.

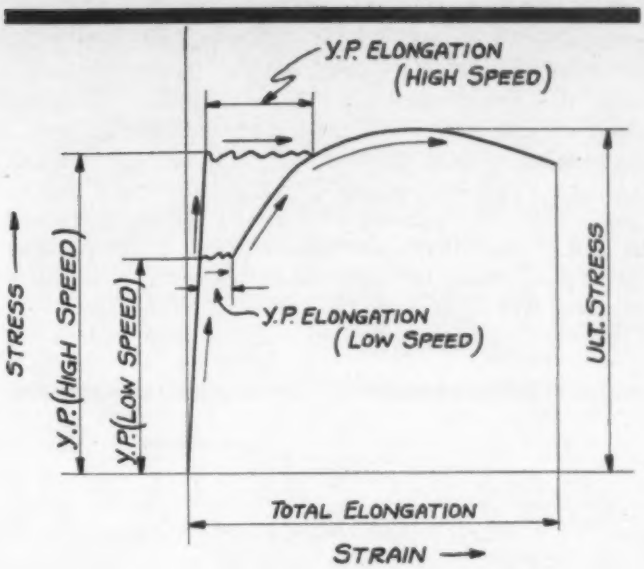
It had been determined fairly early in the study of the behavior of sheets for deep drawing that the formation of stretcher strains was intimately connected with the existence of yield point elongation [5]. In fact, it was even proposed that the depth of surface depressions involved in the stretcher-strain pattern was directly proportional to the percentage of yield point elongation. It must be kept in mind that these phenomena are observed only in low carbon steels, and most objectionably in the fully annealed or "dead-soft" condition. This, of course, is the condition in which the strip finds itself just prior to tempering. It is further known that a quenching treatment would reduce the yield point elongation greatly, if only temporarily. Slight cold reduction would definitely eliminate this phenomenon, and attendant stretcher-straining. A quantitative study

of this effect was made by Hayes and Burns [4] and they developed an interesting relation between size of work roll and the required reduction (or elongation) by rolling necessary to eliminate a given amount of yield point elongation. For instance, it was found that a 4 per cent yield point elongation could be suppressed by reducing the strip only 0.8 per cent on a 4 in. diameter work-roll mill, while 2.0 per cent reduction was required on a 26 in. diameter work-roll mill. These are significant facts, and are of considerable interest. Referring to Figure 8, it is the writer's view that it would take a 4 per cent elongation, by pure stretching, to suppress a 4 per cent yield point elongation. And further, even in rolling, a 4 per cent working is undoubtedly still required near the surface. These facts seem to indicate that a 4 in. diameter roll, producing an average elongation of 0.8 per cent, may actually involve a 4 per cent working of the surface. This means differential cold working across the thickness of the strip, a phenomenon to be elaborated on later. The data would further indicate that the large diameter rolls (26 in.), requiring an average elongation of 2 per cent to accomplish a 4 per cent value at the surface, involve less differential cold working. The effect of roller leveling on stretcher strains is less definite, and of a shorter duration. It is known, for example, that the yield point elongation is never quite reduced to zero by the alternate bending involved in roller leveling, but usually enough so that the subsequent drawing involves elongations that pull the material through the remaining curtailed yield point elongation range. Thus, we see the necessity for the tests shown in Figures 4, 5, and 6, as guides to the proper pre-treatment to be provided for in a commercial mill to employ the Uni-temper process, and to meet the largest variety of conditions.

In seeking to discover the most practical construction for the Uni-temper mill, serious thought was given to the incorporation of a roller leveler into a continuous stretching mill, but for the strip speeds contemplated, and with the small diameter of the rolls required for tinplate gauges, rotational speeds of over 2000 rpm would be involved. There were apparent objections, of course, to a machine as simple as the one used in our preliminary tests, as illustrated in Figure 3a. The heavy radial



(a)



(b)

PROPERTIES \ SPEED OF TEST	.0046"/MIN.	10.1"/MIN.
Y.P. ELONGATION	3%	13%
Y.P. STRESS	28,000 #/2 IN.	43,000 #/2 IN.
ULT. STRESS	42,500 #/2 IN.	45,300 #/2 IN.
TOTAL ELONG.	42.5%	41.0%

(a)

Figure 7 — Effect of speed of stretching on mechanical properties of low carbon steel strip, and possible interpretation (after Winlock).

▲

Figure 8 — Illustrating the cold work effect in eliminating yield point elongation.

REQUIRED COLD WORKING TO ELIMINATE YIELD POINT ELONGATION

1) 26"Φ TEMPER ROLLS — 2.0 % } ANSON HAYES
2) 4"Φ " " — 0.8 % }
3) ROLLER LEVELING - NEVER QUITE ELIMINATE
4) TENSION STRETCHING - PROBALLY ABOUT 4%

(b)

pressures imposed on the reels (which must be made collapsible for rapid coil handling) as the coils build up, as well as the scratching tendencies as the strip is coiled while stretching, ruled out this construction. The more likely arrangement indicated in Figure 3b had objections with respect to scratching on the top tension rolls, as well as not permitting a short enough stretch span to prevent guttering, especially for the narrower widths. Detailed consideration of many other possible constructions led to the arrangement that was finally adopted. This is schematically illustrated in Figure 9.

Here we see essentially two 2-high mills built into the same housing, the top mill having its roll setting controlled by a conventional screwdown, and the bottom mill having its roll setting independently set by a screw-up. The bottom roll of the top mill and the top roll of the bottom mill are fixed in spatial position, and are the driven rolls. The extreme top and bottom rolls are idle, being driven by frictional contact with the strip only. The strip enters between the top pair of rolls and wraps around what we have called the No. 2 roll (counting downward) then around the No. 3 roll, and then through the bite of the bottom pair of rolls. By this arrangement, the free span of strip between mills where the greater part of the elongation is constrained to take place, may easily be kept between 10 in. and 15 in., which is well within the limits dictated by the early tests for usual minimum tin plate widths. By virtue of the strip wrapping around the driven rolls, No. 2 and No. 3, they serve to act as tension multipliers as well as to roll the strip slightly, so that, whereas the tension in the strip is slightly above the yield point in the stretch gap, it is reduced to hardly more than half this value at the exit point from the top mill or at the entry point to the bottom mill. This is important.

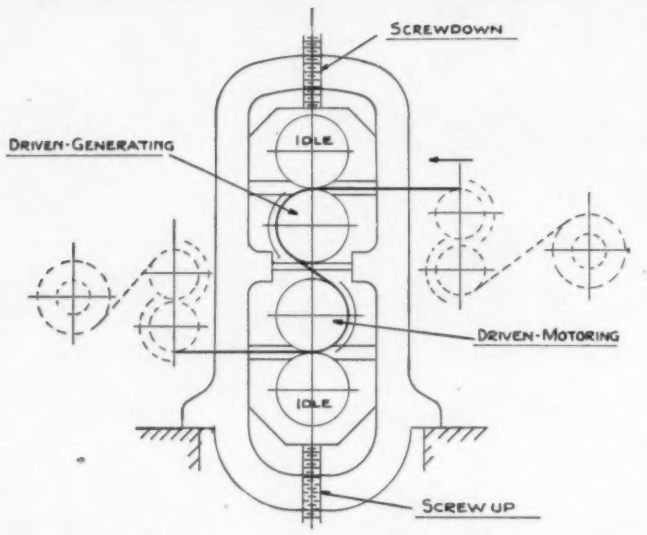


Figure 9 — Preferred arrangement of Uni-temper mill.

The function of the second or lower 2-high mill, in addition to its functions as the pulling pair of rolls and tension multiplier, is to also perform a slight rolling operation, to burnish the strip as a base for subsequent bright electroplating, etc. However, if the stock is to be subsequently vitreous enamelled, this second set of rolls may be deliberately roughened by sand blasting or the like, as the slight roughening or loss of lustre accompanying the stretching operation is not sufficient for this purpose. It is to be understood that the rolls in the first stand may be sand blasted, as well.

An important consideration in the design of the mill is the matter of control between the two mills, and while the principle involved calls for the tension stress to be above the yield point (and of course controlled to be constant, at will), the method of gaining this objective is preferably by controlling the elongation. At least three types of drives were seriously considered in this connection: the change gear drive, the differential gear drive, and the all-electric drive. The first arrangement contemplates a positive geared connection between the two driven elements of the two mills, and involves, for the purpose of obtaining various tempers, a series of change gears, possibly 9 or 12. The driving motor in this case would be relatively small, since it would necessarily supply only the difference in power being transmitted through the two drive spindles. The accuracy of control would be of the closest. There would be a lack of flexibility of control in this arrangement, however, which is not present in the differential gear drive or the all-electric drive. The differential drive would involve a differential gear connected between the two main spindles, but for infinite flexibility of control, two electric motors would be involved — the main drive motor and the differential motor. In addition, an electrical control system would be involved to maintain accurate rotational relationship between these two motors to get accurate temper control. The somewhat smaller mechanical drive than in the first case — although still large for a differential mechanism — would be offset by the increased cost of the additional motor hp involved, as well as the control.

For the first installation, which was necessarily a proving installation, the greatest possible flexibility was desired. As built, the mill differed somewhat from that shown in Figure 9, mainly to permit modifications if necessary; it was built with the all-electric drive. While still recognizing it to be a pilot installation, a top speed of 3000 fpm was chosen to fully explore its possibilities. Based on getting the highest hardness desired in tin plate in one pass through the mill, a maximum elongation of 12 per cent was provided for. Based on stretching the strip at the maximum speed and for the highest tempers, a tension stress in the strip of better than 50,000 psi was used. Rolls, with diameters of 24 in. maximum, wearing down to 22 in., were settled on, equipped with film type bearings; both iron and steel rolls were furnished with the original installation. Following to a large extent the conventional practice on temper mills, entry and delivery tension roll stands were furnished, each roll being separately driven and electrically interconnected with the theoretically best load division. A regenerative type uncoiler and collapsing reel and belt wrapper completed the auxiliary equipment. The matter of automatic threading was very satisfactorily worked out by providing guides, as indicated in Figure 9, which control the strip passage through the mill without manual assistance, once started. To aid in rolling the strip in the top mill during the entering stages, an anti-crimping roll assembly, pneumatically retractable, was subsequently installed.

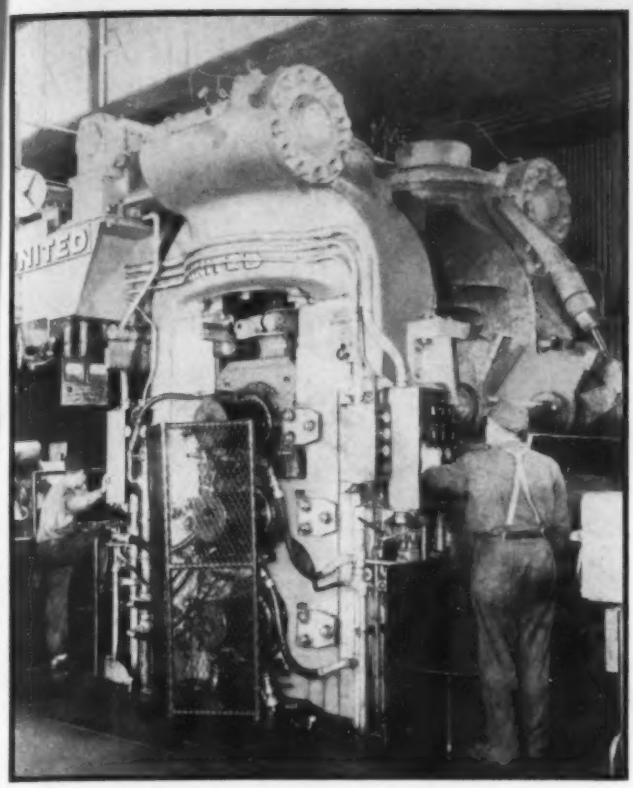


Figure 10 — Operator's side of Uni-temper mill. (above)

Figure 11 — Delivery end of Uni-temper mill. (right)

Figure 12 — Entry end of Uni-temper mill. (bottom right)

The matter of the proper motor selection, particularly for the main drives, had to be made with no precedent to fall back on. It was appreciated at the outset that the little reduction required in the first mill would involve so little power that not only would a driving motor not be necessary — but that the motor would have to generate, after the threading period, in order to provide enough resistance to the forward motion of the strip to stretch it above the yield point. The pulling units, then, were the reel, the delivery tension stand, and the lower or No. 2 mill, with the reaction being furnished by the combination of No. 1 mill, entry tension rolls, and uncoiler. Accordingly a 1500 hp, 300/600 rpm motor was used for the No. 2 mill, direct driven, and a 500 hp, 250/500 rpm direct driven motor (generator) for the No. 1 stand. The tension rolls were also direct connected, the entry rolls being connected to 50 kw and 100 kw generators, respectively, with the delivery tension rolls driven by 150 hp and 300 hp motors. The uncoiler heads were furnished with two 25 kw generators, and the reel with a 150 hp, 150/600 rpm direct connected motor. Figures 10, 11, and 12 show the operator's side and the delivery and entry ends of the mill, and give a clear idea of how this installation was made. Since all motors act together during the threading stage, the Ward-Leonard motor generator set capacity furnished was 1250 kw. An excellently worked-out control system for automatic control of the relative speed of the two mills permitted elongation control at maximum operating speeds of 1/10 of 1 per cent. Such accuracy, of course, was not maintained at lower speeds nor during the accelerating and decelerating periods, but eminently satisfactory control was to be had for all operating conditions. It must be said at this point that, while this first pilot installation met our best expectations, the next installation will be altered in some several details, so as to facilitate roll changing, to improve coil handling, and to balance better the electrical loads.

This mill has now been in operation about two years, and although the war impeded its start and delayed its further development, a great amount of experience has been gained, a great many expectations confirmed, and a large number of "bugs" worked out, both as to mill operation and product. For this, we acknowledge the courage of the Republic Steel Corporation for installing this new type of mill, and we are indebted to them for great assistance in working out the problems attending the use of such new equipment.

The operational characteristics of the mill presented many new and interesting problems. Although it was anticipated, as already said, that perhaps the strip might have to be side trimmed ahead of the mill — say in the electrolytic cleaning line — this was found very early to be unnecessary. In fact, many coils with actual cracked edges have gone through the mill, and come out with only accentuated cracks, not torn through. This has amazed most operators who have witnessed the operation, being familiar with the continual breakage of strip in tandem rolling, when inter-stand tensions begin to approach 40,000 psi even though still below

the yield point, as must be the case in such a mill arrangement. This is in a large measure, or perhaps entirely, due to the method of elongation control adopted, i.e., controlling the relative speed of the mills to produce constant elongation rather than attempting to control tension as such. Thus, as a crack progresses, since the elongation is maintained constant, the tension decreases to such a point that the growth of the tear is arrested until the strip is through the mill and onto the reel. Another factor that undoubtedly enters is the short time that the strip is being stretched — only 1/30 sec, at top speed. Of course, the sheet cut from the strip containing the tear is scrap, but from the production point of view, a cobble has not resulted.

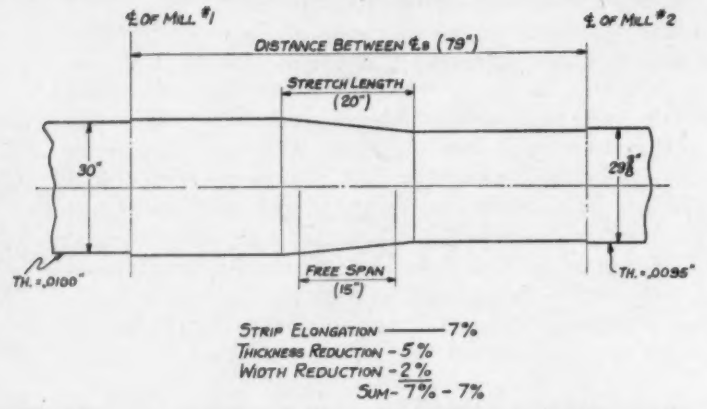


Figure 13 — Strip width at various points in passage through the Uni-temper mill.

Many of the results obtained were as expected, based on the preliminary studies. No cases of guttering or longitudinal corrugations have occurred, because of the short stretch span utilized. In learning to operate the mill, all combinations of mill settings, tension settings, etc., were tried out. It was learned, for instance, that if the No. 1 mill were set too lightly, stretcher strains would form that were not pulled through in the stretching operation. At the high rates of elongation used (up to 300 per cent per second — some 40 times the highest value checked by Winlock), it was clearly expected that this would be the case. Moreover, if No. 1 mill were set too heavily and the rolls were accordingly contoured to obtain flat strip, then diagonal edge scratches resulted, occurring primarily near the bite of the rolls. Normally, the roll settings in the two mills are such as to give about ¼ of 1 per cent reduction, made by passing sheets through the stands. These values are increased somewhat when strip is being rolled through, due to front and back tension on either side of the mill bite. Thus, if a 7 per cent total elongation is to be obtained in the final uni-tempered product, from 6 to 6½ per cent is by pure stretch and the remainder by rolling in the two stands.

In order to get an accurate understanding of how the mill operates, strip has been stopped in the mill by pushing the emergency button, stopping the strip, going at say 200 fpm, in a matter of 2 feet. The mill rolls were then opened, the strip removed, and a picture such as shown in Figure 13 obtained. The length of the stretch span was easily recognized by the section in which the width change was entirely confined except for the slight spreading corresponding to the roll bites proper. The change of width was gradual from one end of the stretch span to the other, which, as is to be expected, is somewhat longer than the free span. This is explained by the short distance around the roll in which the tension drops down to a point below the yield point. It is seen, therefore, that the strip, in passing through the Uni-temper mill, passes through three distinct plastic working stages, separated by two elastic stages. For instance, a 30 in. wide strip, .010 in. thick, being elongated 7 per cent, will reduce in width to 29⅜ in. and in thickness to 0.0095 in. — a 2 per cent reduction in width, and a 5 per cent reduction in thickness. We wish to point out here that, in any plastic operation, constant volume is maintained, and for small changes, per cent change in length + per cent change in width + per cent change in thickness = 0. Thus, in operating the Uni-temper mill, proper allowance is made for this narrowing when planning for a desired final slit width of strip.

One of the original matters of concern was what would happen at the top speed of 3000 fpm. As is well known, the higher the speed of cold rolling, the higher the strip temperature and hence, the roll temperatures, unless adequate cooling is provided — and in a temper mill, this is not possible. The mill, therefore, was run at high speeds until thermal equilibrium was reached, and then stopped quickly, and a temperature traverse taken across the face of the roll. This showed only 90 F in the middle of the roll (hand warm), increasing to about 125 F near each end of the roll body. This extremely low temperature is because of the low power consumed in uni-tempering strip, and it is thus evident that there is no limit to the speed at which such a mill can be run, at least from the thermal point of view. Actually an interesting circumstance developed because of this low heat generation in the roll bite. Even with the low loss, film type bearings now in common use on high speed mills and applied in this unit, the mass oil temperature leaving the bearings will reach 140 F when entering at say 100 F or so. In starting up the mill, therefore, if the rolls were contoured (be it ever so little) correctly for the initial conditions, over-rolling of the edges would result as the mill warmed up, i.e., as heat generated in the film bearings flowed into the roll necks and increased the roll diameter near the ends. This condition paralleled what happened some fifteen years ago in cold mills, when anti-friction bearings replaced grease-lubricated brasses and alleviated a similar condition. In this case, the difficulty has been obviated in two ways: by using lighter lubricating oils going into the bearings at lower temperatures, and by providing gas jets for heating the roll eenters as the mill comes up to production. Probably only the latter is necessary.

A word might well be said here concerning the flatness of the product obtainable with this type of mill. Since its fundamental principle might be called that of a continuous stretcher leveler, the possibilities presented are immediately apparent. All that is required is a slight contouring of the rolls to compensate for the low pressure used, principally in the starting-up condition, and extreme flatness can be obtained. The possibilities of this mill, operated for the specific purpose of continuous leveling, gives real promise in other fields, such as

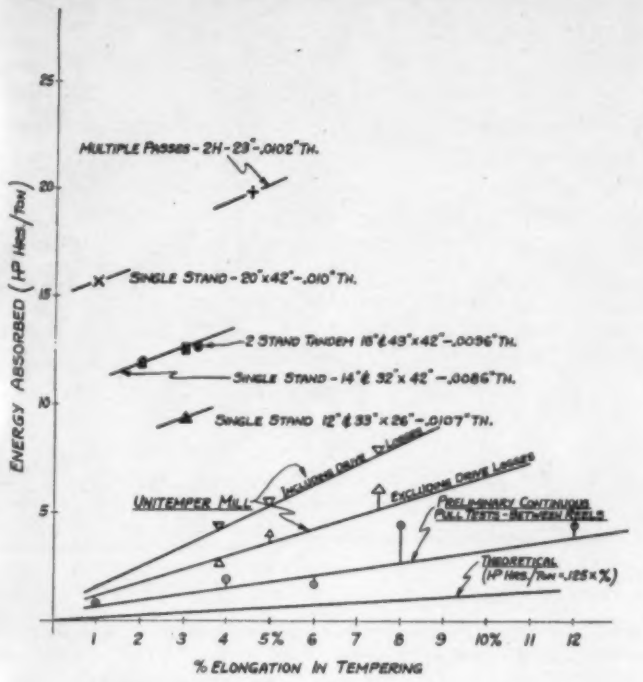

ENERGY ABSORBED (HP HRS./TON)
25
20
15
10
5
MULTIPLE PASSES - 2H - 23"-.0102"TH.
SINGLE STAND - 20"x42"-.010"TH.
2 STAND TANDEM 18"&43"x42"-.0096"TH.
SINGLE STAND - 14"& 32"x 42" -.0086"TH.
SINGLE STAND 12"& 33"x 26"-.0107"TH.
UNITEMPER MILL
INCLUDING DRIVE & LOSSES
EXCLUDING DRIVE LOSSES
PRELIMINARY CONTINUOUS PULL TESTS - BETWEEN REELS
THEORETICAL (HP HRS./TON = .125 x %)
1 2 3 4 5% 6 7 8 9 10% 11 12
% ELONGATION IN TEMPERING

Figure 14 — Energy consumption of various types and arrangements of temper mills rolling tin plate.

for furniture stock, duralumin strip, etc., as well as for tinplate.

The matter of bearings and rolls has turned out to be a particularly happy one. Due to the small amount of reduction actually taken in the mills proper, rolling pressures average around 20,000 psi, varying from 15,000 to 25,000 psi. This, as is appreciated, is around ⅓ to ¼ of that met in usual temper rolling, and is responsible for greatly increased roll life. Because of these low pressures, cast iron rolls have an excellent chance of being the roll for the mill. In the starting-up days, steel rolls were preferred because of their somewhat greater resistance to marking when accidents occurred, such as strip going through double, etc., but with more familiar operation, these objections are being eliminated and a further attractive saving in roll cost is already being shown by the introduction of iron rolls.

The matter of the power required to Uni-temper, as compared to that required for rolling, is another significant point of comparison. Such a comparative study is shown in Figure 14. Examine first the theoretical hp-hr per ton required to elongate strip as shown in the lower curve, and concentrate on the 5 per cent value, for instance. About 0.6 hp-hr per ton is all that is theoretically required. From the scattered values plotted from tests made on various types of temper mills, we see that values range from 10 to 20 hp-hr per ton, revealing the low efficiency of temper mills as a class, around 4 per cent. Of interest is the second from the lowest curve, showing the power readings taken during the first continuous tests made, when pulling between reels. Values of the order of 1.7 hp-hr per ton at 5 per cent elongation are indicated. The curves marked Uni-temper show the average of many tests, and show first the power required by the mill itself and then the total required by the mill plus uncoiling and reeling equipment, including all drive and electrical losses. Even this latter curve shows a power saving of from ½ to ⅔ of that usually consumed.

So far, nothing has been said concerning the products from the mill, but it is felt that here too a contribution has been made. In early photomicrographic studies, material that had been stretched 12 per cent was compared to other strip that had been temper-rolled but 6 per cent. The examination revealed little or no grain elongation in the former case, whereas in the latter it was easy to detect the direction of rolling. It was anticipated that this different method of cold working strip would result in quite different physical properties, and in this, tests on products from the mill have confirmed preliminary tests made on the early sheet product.

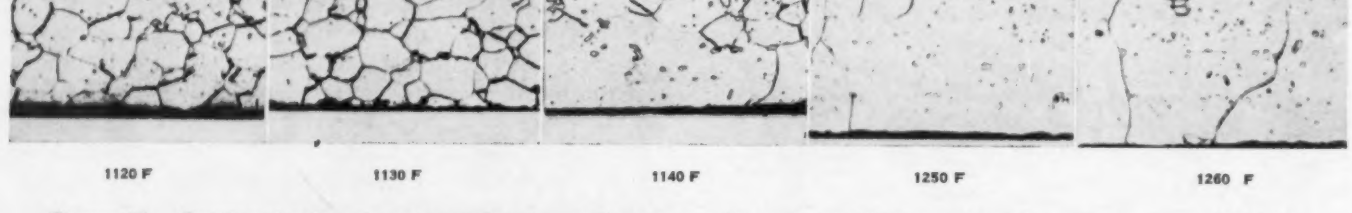
In general, it can be said that the uni-tempered product reveals greater elongation or ductility for a given hardness than conventionally rolled tin plate. This means that the material combines the strength or stiffness required for can bodies (non-fluting, etc.) with the ductility required for can tops (drawability, etc.). Of particular interest are the desirable "spring-back" characteristics of the Uni-temper product. A comparison of longitudinal and transverse properties have shown that there is less directionality of properties than in rolled plate — and therefore less attention need be paid as to how the material is placed in the forming machinery. Added to all this, a large number of tests have shown that a different relationship exists between hardness (T-numbers), yield point, ultimate stress, per cent of elongation, Olsen, etc., than is the case for rolled tin plate, and it has been necessary for the producer to develop a new set of standards by which to judge the applicability of a given plate to a given product.

Many tests were run to determine the percentages of elongation required to obtain certain tempers (T-numbers), since this is the most widely accepted method of classifying tinplate. And such tests included rephosphorized steels and killed steels, as well as rimming steels. Although such a product is not generally accepted for cans, it has been demonstrated that not only T-4, but T-5 can be obtained in one pass through the mill, using rimming steel.

Naturally, there has been considerable thought given to the explanation of the difference in properties between strip cold processed in the two different ways. And there still remains more to be done. But we do know there is a considerable difference in the way the cold working is distributed throughout the thickness of the strip. This question has been controversial for some time, some people maintaining that the steel cannot help but be uniformly cold worked throughout, since each section is equally reduced. To throw more light on the matter, some years ago, a series of tests was subsidized at Massachusetts Institute of Technology [5], in which bars 1 in. x 1 in. were cold rolled through a pair of rolls in various ways (direct, reversing, using various reductions, etc.) and the strain deformation studied by quantitative measurements of net work distortions scribed on the sides of the bar. The results of these tests showed that the shearing strains were always the greatest in the outside fibers of the bars, and since plastic flow is considered mainly to be a slip or shear deformation, we should expect the cold work effect to

1120 F 1130 F 1140 F 1250 F 1260 F

Figure 15 — Sectional microstructures showing differential cold work in .010 in. strip which was temper rolled in conventional 4-high mill having 14.8 in. work rolls.

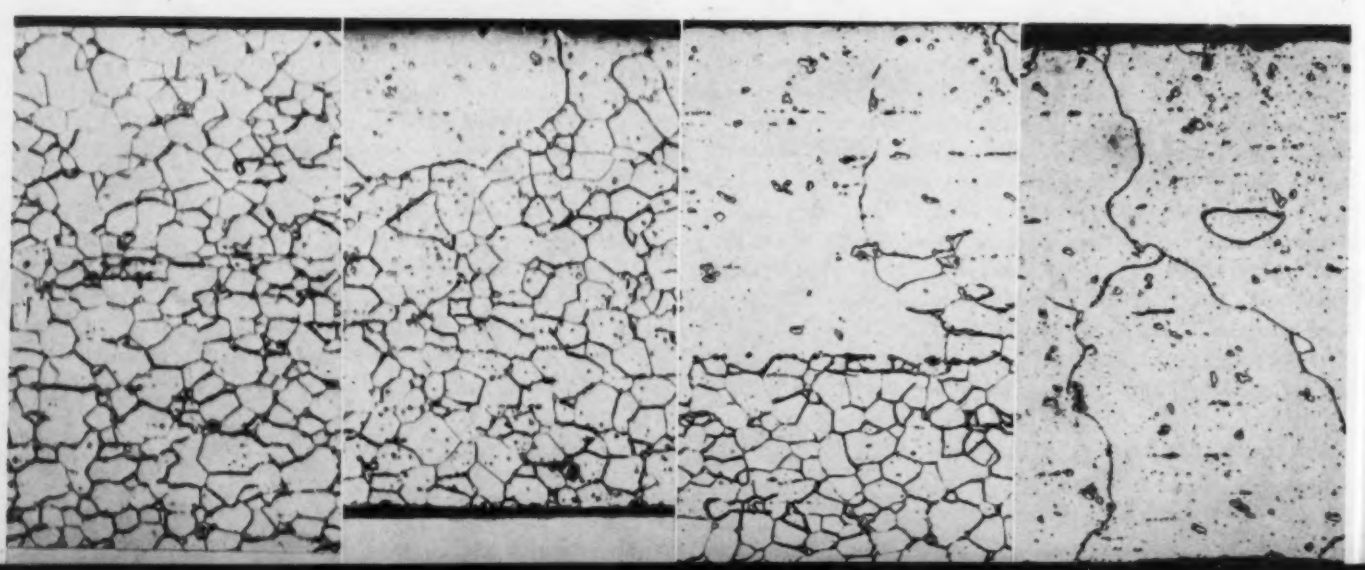


1120 F 1130 F 1140 F 1220 F 1230 F

Figure 16 — Section microstructures showing differential cold work in .010 in. sheet which was temper rolled in old fashioned 2-high mills.

Figure 17 — Sectional microstructures showing differential cold work in .010 in. strip which was tension tempered in Uni-temper mill.

1240 F 1250 F 1290 F 1300 F



be greatest on the outside. These tests, however, could not be considered to be conclusive in this regard, since the width of the bars was narrow with respect to the thickness and spreading would take place more at the outside in contact with the roll surfaces.

Various attempts have been made to examine the cross-sections of tempered tin plate under a powerful microscope, but such visual examination has always been inconclusive. In an effort to follow through on this matter, several samples were submitted to C. S. Barrett, Carnegie Institute of Technology, for X-ray studies, but the patterns obtained were also inconclusive in this case, due to the amount of cold work and the grain size. He suggested, however, that a careful job of annealing at various temperatures might reveal any differential cold work, by appearance of preferentially recrystallized layers, based on the well-known effect of cold work depressing the recrystallization temperature. Accordingly, strip taken from the same heat of steel and processed the same up to the temper stage, was tempered in three different manners: (a) on a conventional 4-high mill; (b) on an old-fashioned 2-high mill; and (c) by uni-tempering. Each sample was temper elongated about 7 per cent. Several samples of each were prepared and were annealed very carefully in a vacuum furnace to prevent oxidizing away the outer layers that were, particularly, to be studied. Various annealing temperatures were used, starting at 1000 F, and the material was held for two hours. Temperature steps of 10 degrees were used, requiring accurate furnace control. Especially careful etching and polishing technique was used in bringing out the structure.

Figure 15 shows several photomicrographs (300 X) of tin plate, temper rolled in the conventional 4-high mill having 14.84 in. diameter work rolls, and then annealed at 1120 F to 1260 F. The first picture shows the original structure just starting to recrystallize at the edge, and the last picture shows the entire section completely recrystallized. These pictures prove definitely the existence of differential cold work, the temperature range of 140 degrees being somewhat a measure of this variation. The lowest recrystallization temperature is also somewhat of a measure of the maximum degree of cold work. Figure 16 shows similar photomicrographs for strip tempered on 2-high mills, having 24 in. diameter rolls; on these samples the surface recrystallization started at 1120 F and recrystallization was complete at 1230 F — a spread of 110 degrees. A comparison of these two indicates that the total amount of cold work was about the same in the two cases, but that the differential amount was more for the 4-high mill with smaller work rolls — 140 degrees compared to 110 degrees. These indications confirm the conclusions drawn from the data quoted earlier. This work is being extended further to investigate the effect of a large range of work roll sizes and also the effect of tension, and will be reported later.

Figure 17 shows uni-tempered tin plate, unaffected at 1240 F, but completely recrystallized through to the center at 1300 F, the actual range being about 50 degrees. This picture strongly supports the early promise as to the quality of the product from the mill.

In conclusion, something should be said about the economics expected from the mill, not considering the contribution from the quality of the product. As has been said earlier, this initial installation was made to prove the process and the product, with provision for modifications as they might arise. Hence it was not designed primarily from the point of view of maximum production. Already, however, the average tonnage from the mill has reached 200 net tons per 8 hr turn, using coils weighing 6000 lb. Certain improvements already under way to facilitate coil handling around the mill, roll changing, etc. should considerably increase this figure, not including the increase due to future larger coils. Already, production costs are attractively low, primarily due to the greatly reduced roll cost, decreased power cost, low maintenance cost, and reduced depreciation. The simplicity and compactness of the design is in itself a demonstration of the relatively low first cost. In the next mill, the production figures should go up and the costs still further down, not taking into account considerably higher strip speeds which are being seriously contemplated.

It is felt that this development has made an auspicious start, and like all such developments, must always be a joint effort of the machinery designer and builder working intimately with the user.

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DISCUSSION

PRESENTED BY

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F. Mohler: Mr. Stone has presented a very complete and interesting paper in connection with this radically new type of temper mill. However, he devoted most of his discussion to the mechanics of the mill and the rolling process. I feel, therefore, that a few words in regard to the electric equipment will not be amiss.

The very fundamental of this mill is the maintenance of very accurate speed relation between the two sets of mill rolls. As Mr. Stone has described, the majority of the reduction is obtained by stretching the strip between these two sets of mill rolls. Thus, if a 5 per cent elongation is to be made, it means that the first set of

(*Please turn to page 67*)

CURRENT DEVELOPMENTS IN

Industrial Lubricants

. . . . under the stress of war demands, developments in lubricants have proceeded rapidly . . . . many of the improvements will be of assistance in improving the economy of post-war operations . . . .

by G. F. BOWERS

STANDARD OIL COMPANY OF INDIANA

CHICAGO, ILLINOIS

▲ IT is invariably true that during war time very rapid progress is made in almost every line of endeavor. During this time the demands are severe, the need for meeting these demands is at a maximum, and cost for the most part is relatively unimportant. The multitude of problems must be solved without regard to economics or other factors considered in peace time projects. This necessity of immediately getting the best performance possible speeds up the entire development. It is true that this procedure requires substituting rapid tests that give indications of performance for the usual long time test methods but the emergency accomplishments justify the actions.

The demands in the war effort have influenced lubricants along two important basic lines: first, the use of the necessary lubricants to keep in operation, as nearly continuously as possible, the equipment already in service even though greater demands were made on this equipment; second, the development of new or improved lubricants to meet the wide range of severe conditions encountered, particularly by the armed forces, in new equipment and new uses of equipment. Although both of the influences are important the second will undoubtedly have the greater influence on post-war products. Naturally there can be no sharp line of demarcation, since products developed for a specific use are offered for other applications when the product characteristics indicate their worth for other problems.

The research departments in the petroleum industry, like other research organizations, work continuously on a great variety of problems. For many reasons, much of their work never sees the light of day commercially; in other instances the products may be used in an extremely limited way. There is, however, the basic knowledge of methods and characteristics, so that in times of stress and emergency, such as a war, these products can be brought forth, modified as necessary, and made available for special uses. Under this system very few entirely new and radically different materials are offered commercially. Rather, because of the economics of the situation or the changed requirements, it is a case of promoting a product from the laboratory to full scale commercial use. Many products which may have been heard of or used in a limited way will become widely used products in the future.

Lubricants cannot be divorced from the method of application. It has been recognized for years that circulating systems and centralized automatic grease systems represent the best methods of lubrication. Currently the need for continuous operation, coupled with the manpower shortage, has resulted in a greatly increased use of automatic and semi-automatic lubricating systems. This change alone has resulted, in a great many cases,

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in the necessity for using a lubricant with different characteristics. This change is more fundamental than merely changing the consistency of the lubricant to secure one that can be dispersed easily by the lubricating appliance. An excellent illustration of this fact is evident when the method of lubricating roll necks is changed from the old hand packed method to a modern lubricating system. With the hand packed method one of the major problems was to have the grease stay in place so there would be some lubrication. With a lubricating system this requirement no longer exists and small amounts of lubricant can be applied as frequently as needed to give maximum lubrication with a minimum cost for the lubricant and for maintenance. It is therefore possible to concentrate on the required characteristics of the lubricant for lubrication without modification because of the shortcomings in the method of application. Under these circumstances it is expected that a few products can be widely used, thus reducing the number of products needed in any given plant.

For many years it has been recognized that the greases available fell far short of having the desired properties and, although there was progress, it was slow and did not as a matter of fact keep pace with the improvements in oils. Soda soap greases were the recognized products to use where high temperatures were encountered. They were open to the objections that they were not suitable in the presence of water and were difficult or impossible to dispense at low temperatures. Lime soap greases, on the other hand, had good dispensing characteristics at low temperatures and good water resistance but were entirely unsuitable for temperatures above approximately 200 F. It was necessary to change the lubricant seasonally or accept inferior performance part of the time. Further, in those instances where one lubricant had to be used when both temperature and water were encountered, unsatisfactory performance of part of the bearings always existed. Naturally the grease manufacturers endeavored to make a high temperature, water resistant grease that had good low temperature dispensing characteristics. Relatively little progress was made until very recently. Both the Army and Navy found it increasingly essential to have greases that could be used through wider temperature ranges. Airplanes based in steaming locations at the equator had to be lubricated with a product that would stay in at such temperatures and still function satisfactorily at temperatures of approximately 60 F below zero during the long hours of flight. Navy vessels plying the oceans from extreme north to south presented problems of extremes of temperature outside the scope of either conventional lime or soda soap greases. These problems were solved by using greases which have the following important characteristics:

1. High temperature properties in that they do not separate when heated to high temperatures and return to approximately their original consistency when cooled.
2. Dispensing or movement properties at low temperatures consistent with the viscosity of the oil used in the grease.
3. Resistance to the action of water comparable to a lime soap grease of the same oil viscosity.
4. Essentially the same consistency before and after working in an A. S. T. M. grease churn.

This type of product is available now to a certain degree and can be expected to be more popular in the future. It must not be expected that one grade of grease will be the panacea for all current ills. However, a few grades of this type with different oil viscosities and with or without extreme pressure characteristics will cover a multitude of applications. The field is broadened and the danger of complete misapplication essentially eliminated.

The stability, or resistance to oxidation, of greases is another property of great importance to both the manufacturer and the user. Continual effort is made to improve the quality of the basic ingredients and thus improve the quality of the finished grease. Further, the search for better additives results in improvements. These improvements may be in the form of the same stability for a longer time, better stability for the same time or good stability covering a wider range of conditions. Such improvements are of direct value to the user.

One of the most difficult problems encountered by the lubrication engineer is gear lubrication. This is true in all lines of industry but is particularly true in steel mills, where the danger of contamination with foreign material is so great. The scale, water, high normal loads and excessively high momentary loads complicate an already severe problem. In addition, the demand for increased output and changes in the characteristics of the steel invariably increase the demands on the gear sets after they have been designed for a certain output. These added demands place an added burden on the lubricant. Since more work is done the temperatures are higher and the viscosity of the lubricant at the new working temperature correspondingly reduced. Further, this higher temperature sharply increases the rate of oxidation or deterioration of the lubricant. These factors, therefore, have two important adverse effects: first, the amount of protection offered by the lubricant is less whether or not an extreme pressure condition exists because of the lower viscosity at the higher temperature, and second, the useful life of the lubricant is shortened because of the more rapid deterioration under the more severe operating conditions. Obviously one way to compensate for these adverse factors is to control the temperature of the lubricant within the range most desirable for the particular conditions; however, rarely indeed is it possible to increase the amount of the lubricant through increased capacity of the reservoir, or to add a cooling unit to an existing installation.

The trend has been, and undoubtedly will continue, in the direction of transmitting more power through smaller units. There are several reasons for this, some of them being:

1. Improved quality of the steel.
2. Increased gear strength secured by improved surface finish, shot blasting, etc.
3. Lower cost of smaller power transmission set.
4. Smaller space required for transmitting a given amount of power.

These and the other factors resulting in the use of smaller units place added requirements on the lubricant. The manufacturers of the equipment recognize the problem and are making real progress in designs to give improved cooling, circulation, etc.

The manufacturers of lubricants are also keenly aware of their problems and can offer progress along three important basic lines:

1. The day of the old style residuum material (so-called gear shield) for unenclosed gears is rapidly passing. Improved methods of application, such as spraying and special guns, have hastened the change. Products which are actually lubricants, that will carry greater loads, that will last several times longer and that greatly reduce the waste of material formerly poured on the floor or thrown off give superior performance in the form of greatly reduced maintenance and lubricant costs. Since they are applied cold the cost, trouble, and waste involved in the old heating process are eliminated.
2. The introduction of extreme pressure lubricants was one of the most important contributions ever made in the field of gear lubrication. These products have been in use for some years but improvements are still being made. The quality of the extreme pressure agents is improved and the number of them available is greater, so that lubricants with highly special characteristics can be available to meet particular requirements. Much has been done in this field and much more will be done in the future.
3. The quality of the oil as used or as blended with other products to give the finished lubricant is extremely important. Improvements in the quality of the oils, particularly in the higher viscosity range make available products which are better able to withstand the rigors of the added requirements previously discussed.

This paper would in no sense be complete without at least a brief mention of additives in lubricants. Additives are essential to many modern lubricants and after the war will be used in increasing amounts for an increasing number of applications. These products are added for detergency, to reduce the pour point, to minimize oxidation, to prevent corrosion, to reduce wear, to change surface tension, to improve the viscosity index, or in other words impart to the lubricant many special properties to make it more suitable for a particular application and to permit the use of only one product for a greater variety of applications. After the war more and a greater variety of these materials will be used. While it is true that in some instances operating practices must be changed, these changes are more than justified on the basis of the superior overall performance secured through the use of the special additive containing lubricants.

It is normal for refinements in the art of making oils to continue and the improvement in quality, particularly in oils in the higher viscosity range, will give oils superior to those used in the past. Such improvement will naturally raise the quality of the entire line of petroleum products.

During the war the chemists and engineers have again proved the fact that no problem is too difficult to be solved and no task too difficult to accomplish. Synthetic oils, finished products resulting from controlled chemical reactions, now available in limited quantities will become increasingly important. These products have been scientifically made to have special properties. They have a good viscosity index, low pour point and essentially no carbon residue. For example, a product with a viscosity of 150 SSU at 210 F would have a carbon residue of less than 0.15 per cent. These products will aid in supplying the lubricants of the future.

Strictly speaking, rust preventives are not lubricants and therefore would not be covered in a paper on lubricants. During the war, however, their use has been imperative and great strides made in improving the quality and physical properties of rust preventives. Further, all industry has become rust preventive conscious, not only to protect products being shipped but also to save the equipment on hand since it could not be replaced. Undoubtedly the use of rust preventives will be continued after the war. The post-war products will be superior to their pre-war counterparts, particularly in the following respects:

1. Greater ease of application.
2. Longer and better protection.
3. Larger selection for special uses.

The proper application of the correct rust preventive will be an important phase of the work of the lubrication engineer.

It must not be expected that after the war the field of lubrication will be Utopia since, as always when the qualities of the lubricants are improved, the demands on them will be increased. Improved lubricants will be available to industry, however, to aid them in meeting the many and complicated problems in the post-war period.

DISCUSSION

PRESENTED BY

R. S. SHOEMAKER, Lubrication Engineer, American Rolling Mill Company, Middletown, Ohio.

C. A. BAILEY, Lubrication Engineer, Carnegie-Illinois Steel Corporation, Gary Works, Gary, Indiana.

G. F. BOWERS, Standard Oil Company (Indiana), Chicago, Illinois.

E. J. EHRET, District Representative, The Farval Corporation, Chicago, Illinois.

R. S. Shoemaker: My hat is off to the oil companies. They have done a splendid job of taking care of their regular customers during the stress of taking care of Uncle Sam's requirements. We have had to make extremely few substitutions, and deliveries have been good. They have not taken advantage of a seller's market.

Reference to rustproofing oils is well taken at this time. Such products are bound to be in demand. I believe there is a decided need for standard specifications covering at least two or more grades of light and heavy material. It is quite a burden and considerable cost is involved in carrying and applying the long list of special slushing oils which customers specify. Some of these so-called rust preventives have little merit and only exist because some oil salesman has done a good selling job.

The American Iron and Steel Institute have had a

committee working on rustproofing applications, methods and materials in connection with Lend-Lease shipments. It is certainly to be hoped that this committee will be continued and that their work can be made available for post-war conditions. This committee is chairmaned by John Pelly of Bethlehem Steel Company.

I think we are all anxiously awaiting the day when we may be able to take advantage of the many improvements science has made in lubricants during this war period. There still remain many mechanical motions in the steel plant not properly protected by lubrication. In many cases this is due to excessive temperature and moisture. Lubricants which will give better protection for our hot and wet spots are bound to be popular during the extremely competitive period ahead. It is up to the lubrication engineer to demonstrate their practical worth as soon as they are obtainable.

C. A. Bailey: It is difficult for a consumer to comment on the future developments of a supplier when their organization is constantly striving to develop new products to offer to the trade. However, there is a definite relationship between consumer and supplier in the development and progress of industrial lubrication. This relationship may be summarized under four headings:

1. Research by the petroleum industry.
2. Improved methods of application by automatic devices.
3. Improved designs by the machinery builder.
4. Coordination of technology of the three preceding groups by the consumer's lubrication engineer.

The phase of research by the petroleum industry has been covered by Mr. Bowers and leaves little to be added by a consumer's lubrication engineer other than his request for products with characteristics to solve his local problems. In this connection one question is directed to Mr. Bowers asking him to comment on the possibility of the use of lithium and barium soap greases in steel mill applications.

It would be possible to mention numerous requests for magic compounds similar to the ones submitted from various departments in my plant. It is common, when a department is helped by a lubrication engineer, to have them come back with other requests for materials to prevent leakage due to bad seals, or to correct other mechanical defects. We are all looking for a magic compound that will stimulate growth of gear teeth, but I hesitate to pass these requests on to the supplier because of dislike for them myself. Therefore, it is preferred to accept this paper as a challenge to lubrication engineers to aid in applying the developments in research offered by the oil companies in the shortest possible time, eliminating lost time that often occurs between development and full application.

The second phase of improved methods of application by automatic devices must strive toward more economical applications at more frequent automatic intervals. We have yet to develop the perfect lubricating device. The benefits of present development are often appreciated more when it is necessary to go back to old methods for a short time. This was the case in the return of the wooden oil drum for a few months. These post-war products would be delivered in leak-proof, self-dispensing containers.

The third phase of this relationship is the machinery builder's design. The research of the petroleum industry and latest lubricant application method is best utilized if incorporated at an early date in the machinery builder's design.

The fourth phase is the coordination of the technology of the three preceding groups by the consumer's lubrication engineer.

The fact that we are being awakened to the need of better care for our machinery is illustrated by the improved service of automobiles and home appliances. This alarm has also been sounded to industry and has resulted in improved practices, such as engineering service, methods, material and, greatest of all, lubrication consciousness. Engineering service can be utilized most effectively if performed by the proper organization. It has been found desirable to have one individual in each department or division assigned the definite responsibility of all lubricants and their application within the department. This procedure has proved very satisfactory and has been carried to the extent that all persons handling lubricants receive instructions from the division lubrication engineer, thus improving the performance of their duties. In many cases it is desirable to have the persons handling lubricants reporting directly or indirectly to the division lubriaction engineer.

The greatest benefits of developments by the research of the petroleum industry will be best realized through efficient application and coordination of lubricating technology.

G. F. Bowers: Mr. Bailey asked a question regarding lithium and barium soap greases. Those and other products can be made to give products which are both heat and water resistant, and are of the type which undoubtedly will become important in lubricants of the future.

E. J. Ehret: We long ago learned that good lubrication calls for, first of all, the correct lubricant and, secondly, the correct method of application which will provide the right amount at frequent enough intervals to prevent metal to metal contact in the bearings.

From these facts we can easily draw the following conclusions: The lubricant should be chosen to suit the bearing requirements, not the lubricating system. You should choose a system that can dispense the lubricant best suited to the bearings. If you compromise on the lubricant to suit the system, you very definitely sacrifice some of the important results obtainable.

To elaborate, places surrounded with heat require first of all a rather heavy bodied product with higher heat resisting qualities and then a method of delivering that lubricant to the bearings at very frequent intervals, so that there is always fresh lubricant in the bearings and the old lubricant is flushed out. Some systems due to their basic design, handle heavier lubricants than others. We are very pleased to hear that lubricants are being developed that maintain their stability over a wide range of temperature changes.

Lubricant manufacturers, in recommending the correct lubricant, might very well point out that the best results can be obtained by the proper system of economical application. In order to do this they should establish which of their lubricants can be handled by the various systems.

THE *Electronic Frequency Changer*

. . . . the electronic frequency changer is a useful tool now available for certain applications previously using other types of equipment . . . . this paper describes an installation in daily use as an interconnection between 60 cycle and 25 cycle power systems . . . .

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▲ IN December, 1943, there went into operation an electronic means of automatically transferring an adjustable but constant amount of power, reversibly, between power systems of different frequencies. This installation, consisting of two 10,000 kw duplicate electronic frequency changers, was made at the Edgar Thomson Works of the Carnegie-Illinois Steel Corporation at Braddock, Pennsylvania, to interconnect their 44 kv, 25 cycle system with their 69 kv, 60 cycle system. The work was undertaken after a group of Carnegie-Illinois Steel Corporation engineers made a thorough review of electronic converter developments in 1940-41.

The 60 cycle system comprises steel mill loads and 50,000 kw of generating capacity, inter-connected with a large public utility having over 600,000 kw in generation. (Figure 1) The steel company's 25 cycle equipment has over 125,000 kw in generation as well as steel mill load. During December, 1943, the first 10,000 kw unit was put into operation followed, in February, 1944, by the second 10,000 kw unit.

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WHAT IS AN ELECTRONIC CONVERTER?

The term "electronic converter" defines a combination of electronic tubes and necessary auxiliaries, which modifies one form of electric power to another form of electric power. The electronic rectifier converts alternating to direct current. Another form transforms direct current into alternating current, in which case it is called an inverter. A rectifier and an inverter in combination transform alternating current of one frequency to alternating current of the same or of a different frequency and may be termed a "frequency changer." A number of different circuits may be used and the type of electronic tube may be varied to accomplish the desired results.

The electronic frequency changer, characteristically, forms a controlled power system interconnection. Some of the controls that appear useful are summarized as follows:

1. Control to give constant power output to one of two systems.
2. Convenient reversibility of power output in response to a predetermined signal.

3. Power output in response to the requirements of a specified portion of a general load may be controlled.
4. Power output in response to the variations in total load of one system and in a predetermined ratio to the power supplied by other sources of that system may be controlled.
5. Power output required to maintain the desired frequency of one system or with frequency regulation characteristics suitable for parallel operation with primer movers may be controlled.
6. Power may be supplied to an otherwise isolated load under frequency regulation characteristics. In this instance certain frequency control and synchronous condenser capacity must be available on the receiving system.

HOW DOES AN ELECTRONIC FREQUENCY CHANGER OPERATE?

Some basic principles of electronics to recall are:

1. Current will flow only when the anode is positive with respect to cathode.
2. Considering a multiphase circuit, only the anode or anodes in the circuit which are most positive will conduct current.
3. It is possible to prevent an anode from conducting, even when it is most positive, by negatively energizing a grid between the anode and cathode.
4. Phase control is the process of varying the time within the cycle at which anode conduction is permitted to begin for the purpose of adjusting the d-c voltage.

Bearing these basic principles in mind, it is possible to show how an electronic frequency changer takes power from one a-c system and delivers power to another a-c system.

Figure 2 shows the connections of a simplified portion of an electronic frequency changer, assumed, for illustration, to be connecting synchronized systems of like frequency. The portion selected is one of several phases. It will be noted that there are two voltages impressed: E_R on the rectifier transformer and E_I on the inverter transformer. The two voltages are in phase and therefore oppose each other. If E_R is increased in magnitude, the anodes of rectifier and inverter are made positive with respect to their cathodes and current, therefore, power will flow from rectifier system to the inverter system, during this portion of a half cycle. In the succeeding half cycle, the tubes will not conduct current, since the polarities are reversed.

The voltages, and therefore the amount of power flow between the rectifier and the inverter, may be varied. This may be accomplished by changing the relative levels of applied system voltages, either at their sources or by changing the taps on the transformers. Still another way is to so energize the grids of the tubes as to make conduction occur at the proper instant. A negatively energized grid can prevent conduction until it is advantageous to permit it to take place.

Considering now a multiphase circuit, with individual rectifiers and inverters in each phase, it becomes apparent that each phase voltage produces a d-c voltage which varies somewhat in magnitude as time progresses,

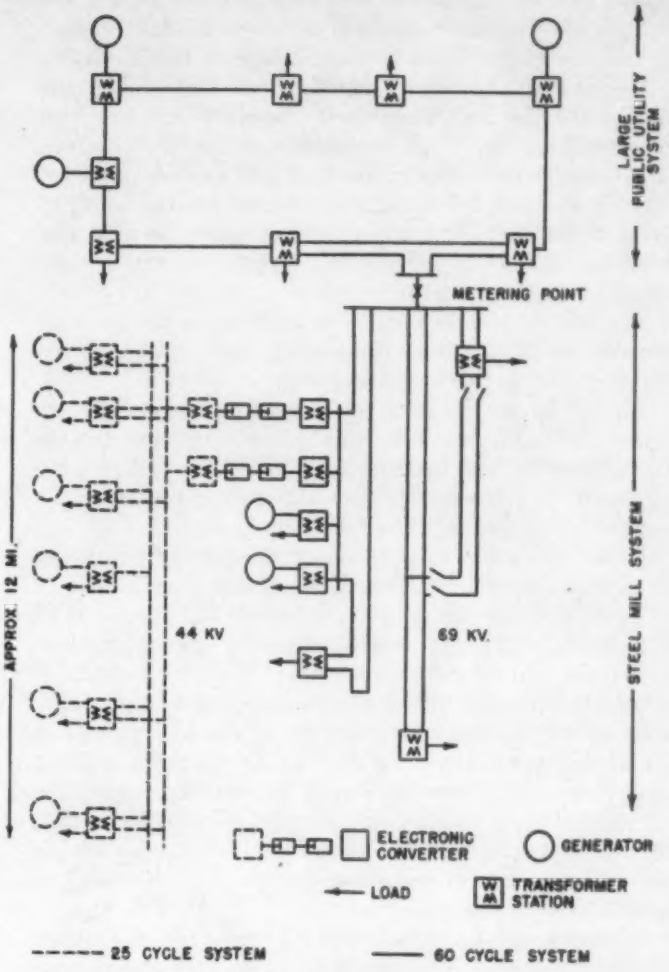
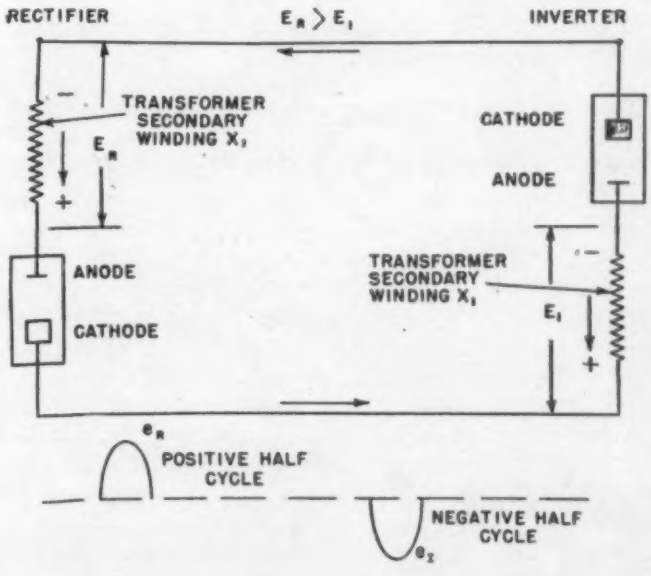


Figure 1 — Electronic converter interconnection of 60 cycle and 25 cycle systems.

Figure 2 — Single phase, half cycle, rectifier-inverter.



yet all phases contribute pieces tending toward a continuity of d-c voltage, which has the desired average value. The various phase rectifiers produce such a d-c voltage and the various phase inverters produce a similar voltage but counter to the voltage of the rectifiers.

By making the phase rectifiers conduct during the portions of the time when their phase voltages are high or by making the inverters conduct during the portions of the time when their phase voltages are low, a difference in average d-c voltage is created which, being in favor of the rectifier, causes current and power to flow from the system supplying the rectifier to the system supplied by the inverter.

The action of the rectifier is to produce an average d-c voltage higher than the average d-c voltage of the inverter, and so produce d-c power.

The action of the inverter is to chop the d-c power, produced by the rectifier, into blocks, corresponding to the phases of the inverter, and, at the correct time intervals, to force multiphase alternating power of the correct frequency into the receiving system.

Phase control is used to block the tubes from firing until is it desirable to have them conduct current.

There are still further refinements in the operation of a frequency changer which warrant some attention. The points to be noted are these:

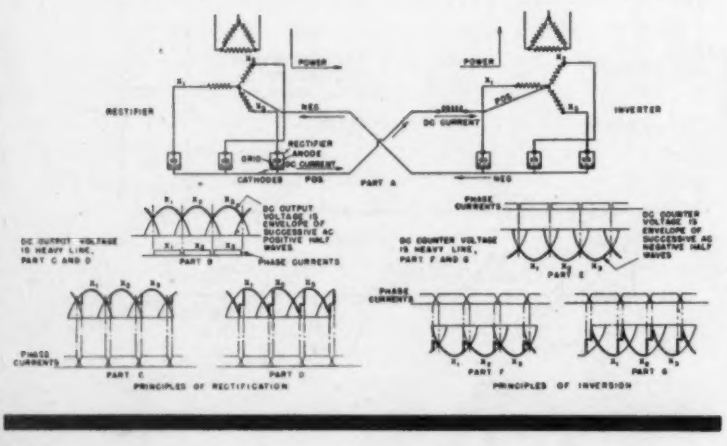
The frequencies of the inter-connected systems may vary at will without affecting the operation of the frequency changer, since the link which connects rectifier to inverter contains only direct current. By taking the signals for phase control of the inverter from the voltage of the receiving system, a-c power is delivered to the receiving system at whatever frequency it happens to have at the moment.

More power is transferred through the frequency changer accordingly as the level of rectifier d-c voltage is raised above the counter d-c voltage of the inverter by phase control, or by transformer tap or by relative rectifier to inverter system voltages.

The direction of power flow may be changed only by phase control of tube conduction at the time to make the anodes of the tubes which are to be the rectifiers positive and give higher d-c voltage than the anodes of the tubes to be the inverters.

Part A of Figure 3 shows the circuit of a simplified 3-phase frequency changer.

Figure 3 — Operating principles of an electronic converter.



Rectifier Operation — Part B shows the voltage waves (positive half cycles) applied to the rectifier.

If these voltage waves could be used as they appear, conduction would occur in all the time periods between intersections of the voltage waves and d-c current would be created in blocks having vertical increases and decreases.

Since the reactance of the circuit does not allow an instantaneous transfer of current from one to another phase, the current in the outgoing phase declines gradually while that of the incoming phase rises gradually, as shown in part C. Notches are thereby introduced in the d-c voltage which tends to lower its average value. These notches increase in area as the load current increases, so giving a drooping voltage with load increases, typical of the rectifier.

Part D shows the effect of preventing conduction in the rectifier by phase control of grid excitation.

It will be observed that the level of instantaneous a-c voltage rises from the intersection of phase voltages to the peak of the succeeding wave. Retarding the conduction of the rectifier tends, therefore, to apply a higher level of voltage to the tubes than would be obtained if conduction took place at the intersection of the phase voltage waves.

It will also be noted that by retarding conduction, current is drawn from the supply system at a phase angle lagging the phase voltage and that this angle increases as load is increased. This characteristic is the chief reason that the rectifier requires a system supply having over excited synchronous capacity on it.

Inverter Operation — Part E of Figure 3 shows the voltage waves impressed on the inverter. These are negative compared to the phase angle of the rectifier voltages.

Again, time, required for transfer of current from one to another phase, prevents this action taking place at the intersection of the voltage waves. In transferring current from one to another phase, advantage is taken of the relatively greater instantaneous values of voltage of the outgoing phase, at instants just preceding intersection as compared to the lower instantaneous voltage of the incoming phase, both voltages being negative. The reactance of the circuit, here acts to increase the voltage (as in part F) of the inverter and gives it a rising characteristic with load increases. Again the current in the outgoing phase declines gradually and that in the incoming phase increases gradually.

Part G shows that conduction in the outgoing phase is prevented by phase control in order to allow the current to be transferred to the next incoming phase before its voltage rises above that of the outgoing phase. Advancing the time at which conduction takes place in the inverter reduces its voltage and allows more power to flow from the rectifier through the inverter to the receiving system.

Again it will be noted that the phase angle relations of the current and voltage of the inverter are such that current leads voltage. This is true when observed from the standpoint of the inverter being a generator. When viewed from the synchronous machines on the receiving system, however, these machines must be overexcited to supply what, to them, is the lagging reactive kva of the inverter.

Margins in angles of phase control of the inverter are

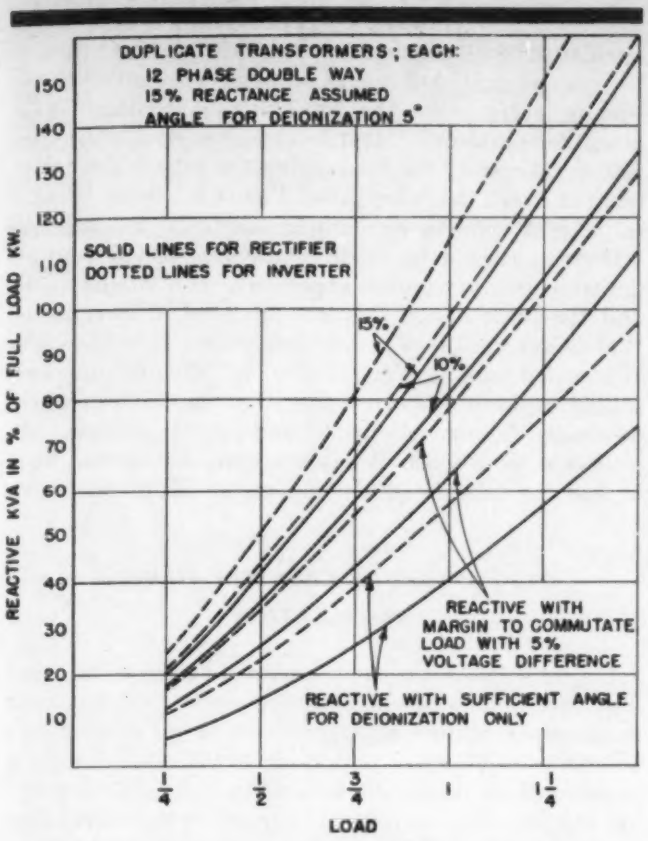
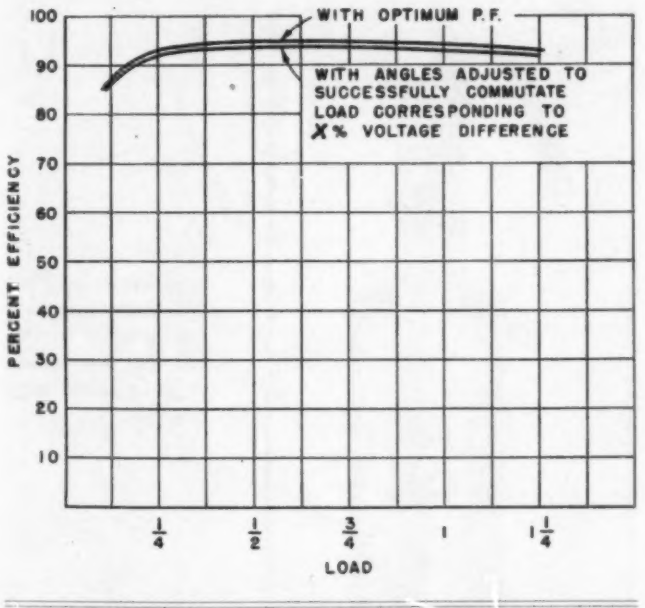


Figure 4 — Reactive kva of a typical electronic converter having identical 12-phase transformers and losses of 5.8 to 6.8 percent.

Figure 5 — Efficiency of a typical electronic converter having a d-c level corresponding to one percent arc loss.



advisable in order that sufficient angle be available for sudden changes in voltages applied.

Figure 4 shows the inherent reactive kva required by both rectifier and inverter. These values are attributable first, to the displacement of current phase position from voltage position, as created by the combination of commutation and phase control; second, to harmonics produced by both rectifiers and inverters, which increase the kva of the system; third, to the magnetizing requirement of the main power transformers, which is observable, chiefly, at light loads.

Power Flow Control — Reversal of the power flow of the converter is accomplished by readjustment of the angles of phase control, accompanied at the proper time by throw-over contacts in the control circuit.

Control of power flow through the converter is responsive to phase control of either rectifier or inverter. Advancing the angle of the rectifier increases d-c applied voltage and advancing the angle of the inverter decreases the d-c counter voltage. Either causes more d-c power to flow.

Efficiency — Figure 5 illustrates the efficiency of a typical electronic power converter, when the d-c voltage level is selected high enough to keep arc losses at approximately 1 per cent. Higher efficiency, as compared to other forms of conversion, is a distinguishing characteristic of the electronic frequency changer. It will be noted that the efficiency is well maintained from ¼ load upward and does not decrease materially from ¼ to ⅛ load. The lower curve represents the efficiencies when the inverter is set for a large margin angle to commutate load fluctuation produced by voltage variation. But even with these adverse conditions, the efficiency is reduced only slightly over 1 per cent.

Electronic Disturbances — Electronic disturbances have been the subject of much research and considerable progress has been made toward the elimination of these types of faults. Arc-backs (failure of grids to prevent conduction during positive half waves) are the characteristic type of internal faults of the rectifiers. Insufficient inverter angle causes commutation failures in the inverter. Both rectifier and inverter commutation failures cause excess current in the rectifier circuits and a-c supply lines feeding the rectifier. Inverter failures cause some current to be furnished by the receiving system to the inverters. High speed relays and contactors are used to stop ignition and bias the grids to cause arc suppression in the rectifier current in a small fraction of a second, whereupon the rectifier or the inverter fault is removed and operation immediately resumes. This action is so fast that it is not necessary to switch off the converter and then restart the service, as is common with conventional low voltage power rectifiers. In the Carnegie installation these faults are limited to about 2 or 3 in a 24 hour period.

System Disturbances — Neither voltage nor frequency variations in sending or receiving system cause the frequency changer to reverse the power flow. This can only be done by changing the angle of the tube ignition. Moderate decreases in receiving system voltage cause a moderate increase in inverter power output. Commutation ceases at about 2.6 times normal power flow. The power regulator restores the previous load within a few seconds, even if the lower voltage persists. Normal current can be restored, after the fault on the receiving system has been cleared, in a minimum of 4/100th second or a maximum of 4/10 second, without the necessity for disconnecting the converter from the system. Since the converter requires reactive kva excitation, the source of this excitation furnishes overcurrent to system disturbances, and provides a signal by means of which they may be cleared by circuit breakers, if the faults persist. So long as these faults are cut off

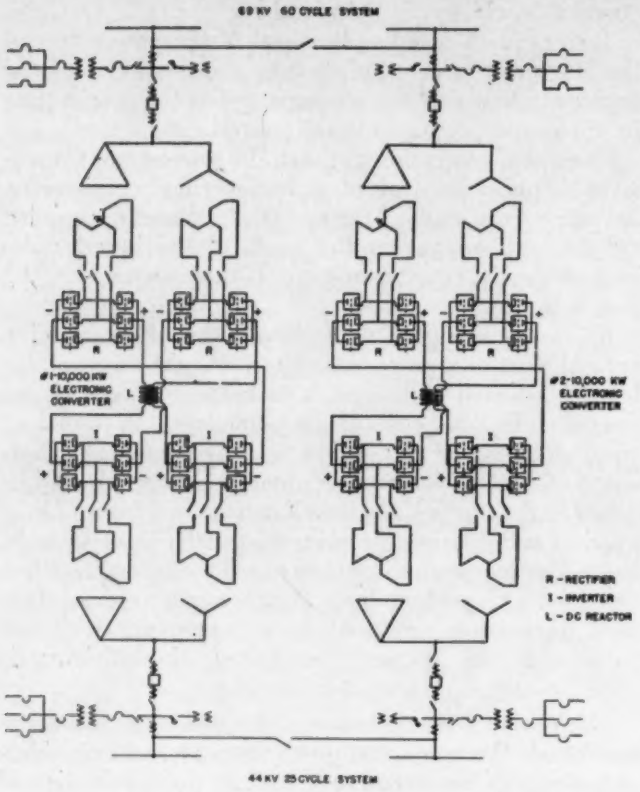

69 KV 60 CYCLE SYSTEM
#1-10,000 KW ELECTRONIC CONVERTER
#2-10,000 KW ELECTRONIC CONVERTER
R - RECTIFIER
I - INVERTER
L - DC REACTOR
44 KV 25 CYCLE SYSTEM

Figure 6 — Main power diagram of an electronic converter.

from the converter in one to three seconds, the arc suppression control will fully protect the frequency changer, making it unnecessary to open the power circuit breakers during that interval. It has been considered good practice to disconnect the converter from a system fault, only if it tends to persist.

Selection of Circuits and Electronic Devices — The simplest and most economical circuits from the standpoint of transformer kva utilization are the double way (full wave) combinations. The circuit used in the Carnegie installation is that shown in Figure 6. Stainless steel, water cooled, sealed, pentode ignitron tubes rated 200 amperes, 20,000 volts, were selected. These tubes have an anode, three grids and a mercury pool cathode. (See Figures 7 and 8.) An igniter establishes a cathode spot each cycle on the mercury pool. The cathode spot is stabilized at low anode currents by the use of an auxiliary holding anode. The first grid, or one nearest the anode, is used as an intermediate anode to divide potential gradients across the tube during non-conducting periods. The second, or center grid, is used to control the starting and conduction period; and the third or outer grid as a shield to permit rapid deionization of the space between the control and shield grid. The design incorporates the lowest possible arc loss consistent with essentially complete freedom from arc-back under normal operating conditions. There are three cathode igniters, only one of which is used at a time, the others being spares. There are also two holding anodes, one maintaining cathode spot excitation for low anode currents and the other is used for control purposes. Both grids must be made positive to establish conduction. If either is negative, the tube will not conduct. Conduction must first be established to the shield grid and then to the control grid. Automatic temperature control of the cooling water keeps the tubes within optimum operating temperatures. Heat exchangers cooled by raw water, take away the losses from the pure water circulated through the tubes. (See Figure 9.) Since there is no way of running accelerated life tests, a conclusive statement cannot be made in the case of the pentode ignitron, but in view of experience with similar tubes and the basic design features involved, it is expected that an average life of at least five years will be obtained. If a sealed tube is ever involved in difficulty, the user simply replaces it and returns it to the factory, where controlled factory conditions and expert personnel are available for rework. It takes approximately one hour or less for tube renewal from power-off to power-on.

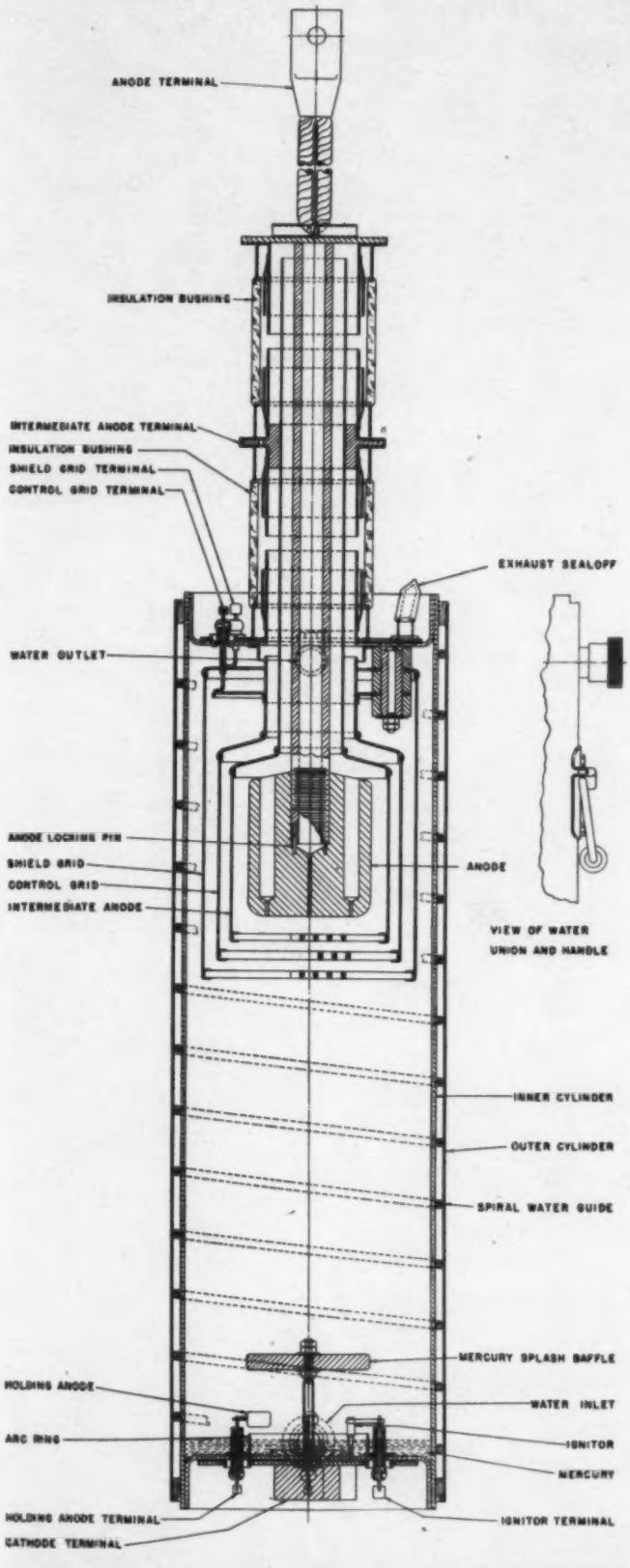
DESCRIPTION OF CARNEGIE-ILLINOIS INSTALLATION

Figure 6 shows the main circuit diagram of the two, duplicate, 10,000 kw electronic frequency changers, used to interconnect the Carnegie-Illinois Steel Corporation's 69,000 volt, 60 cycle and their 44,000 volt, 25 cycle systems. Both the 10,000 kw units are capable of carrying 125 per cent load for two hours and 200 per cent load for one minute. They may be operated singly or in parallel. Transformer connections for each 10,000 kw unit are arranged for 12 phase operation at 12,970 volts. The secondaries are zig-zagged for a phase displacement of plus-minus 7½ electrical degrees, one unit being internally connected for plus 7½ degrees and the other

Figure 7 — The pentode ignitron tube used in the 20,000 kw electronic power converter.

for minus 7½ degrees. This gives 12 phase operation for one unit and 24 phase operation for the two units in parallel. The tubes are connected in eight, 3-phase, double-way (full wave) 6-tube circuits and operate at

Figure 8 — Section through the pentode ignitron showing the general design.



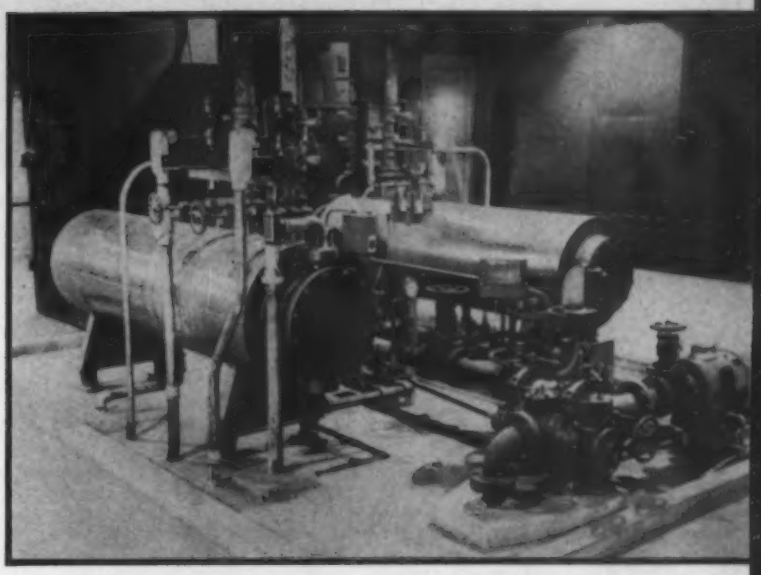


Figure 9 — Unit heat exchangers for two 10,000 kw converters.

29,400 volts, d-c line-to-line. The rectifiers and inverters of each 10,000 kw unit are staggered in the series d-c link. Grounding the neutral of one of the transformer wye points reduces insulation requirements as compared to connecting two rectifiers in series and then the two inverters. By a simple change of connections, operation as a single 20,000 kw unit could be compelled, which points the way to increased kw rating.

It will be noted that there are no power circuit breakers in the d-c circuit. The a-c line breakers are the only ones required.

The multi-storied station, in which the converters are mounted, (See Figure 10) was dictated by the restricted ground area available and by the desire to place damageable portions above high water river level. The heavy transformers, oil circuit breakers and other similar equipment are mounted on concrete or steel pedestals at ground level or just above it (See Figure 11). The windowless, air-conditioned building, supported by ordinary steel columns, houses all the indoor apparatus, while the steel structure provides a mounting for some of the high tension gear. Figure 12 shows the aisle-way extending between pairs of 12 tube cubicles housing sets of tubes and some of their accessories. Figure 13 shows the tubes mounted in their enclosures. The light weight of the electronic equipment proved an advantage in this character of installation. Its adaptability to flat floor surface mounting simplifies and reduces installation cost.

Unattended Station — As the converter station was designed to be unattended but supervised from an adjacent power station where operators are on duty, duplicate operator's panels are provided, one in the converter building and the other in the power station with permissive switches, which transfer complete functional control from one to the other station. Except during trial periods, normal operation of both converters has been directed by the Carnegie-Illinois Steel Corporation load despatcher who has, in general, designated constant power flow, under automatic control, from the 60 to the 25 cycle system.

Effect of Power Reversal — Figure 14 shows by graphic meter charts that load through the converter remains constant at selected levels regardless of voltage and frequency variations in both systems. At approximately 7:40 P.M., the operator reversed the power flow through one unit from 5000 kw to the 25 cycle system to 5000 kw to the 60 cycle system. No corresponding changes were observed in the voltages of the two systems or in the frequency of the 60 cycle system. The extra 10,000 kw load on the already well-loaded 25 cycle generators, however, caused a frequency drop in the 25 cycle system.

System Wave Shapes — Figure 15 shows wave shapes obtained on the high voltage side of 60 and 25 cycle transformers with power flowing from the 60 to the 25 cycle system. The wave distortion for inverters is the same as for rectifiers, and depends upon the same factors. The upper left hand traces A and B show, respectively, the 25 cycle voltage and current with the 10,000 kw inverter operating 12 phase. The upper right hand traces, C and D, show, respectively, the 60 cycle voltage and current of the rectifier when operating in 12 phase. The lower right hand traces, E and F, show the 60 cycle voltage and current of two 10,000 kw rectifiers, when operating in 24 phase. The left hand center traces, a and b, and the right hand center traces, d and e, and the lower left hand traces, e and f, designate the same waves as those identified by the upper register letters, except they were taken when the film was run at a faster speed.

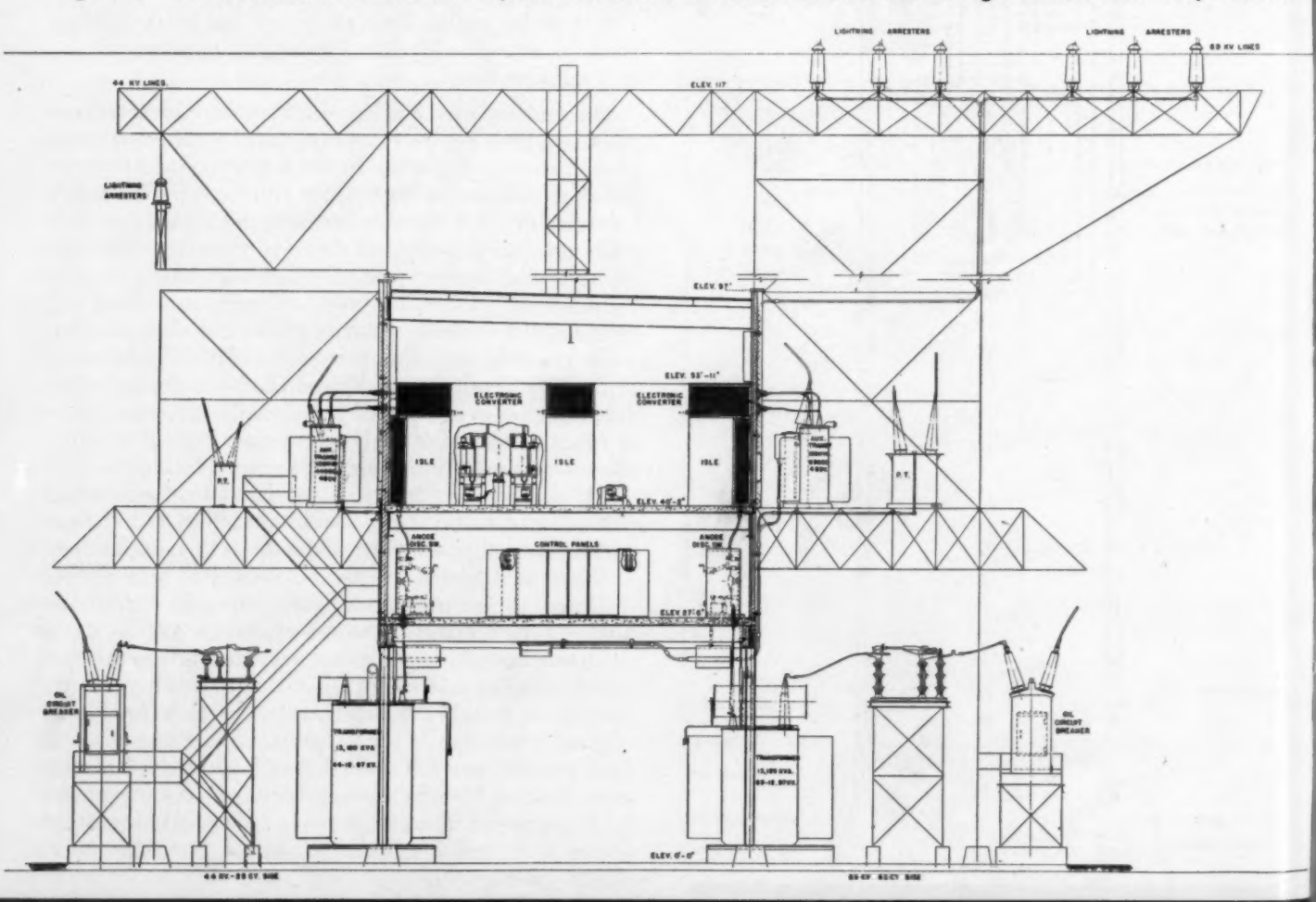
Tests made by representatives of the Edison Electric Institute and Bell Telephone System have shown that no objectionable interference takes place on nearby telephone circuits.

Circuit Control — A unit is switched (Figure 6) in service by merely closing the power circuit breakers connecting the transformers to the two systems, after having energized the auxiliary and ignition transformer circuits and having set the ignition control system network of both frequencies for the inverter position. When the main power circuit breakers are tripped, the automatic control re-establishes this starting condition. For convenience and simplicity of protective relay circuits, both breakers are tripped simultaneously.

The only switching required in the circuit between ignitron tubes and the transformers is for safety to personnel who may have occasion to work on equipment in the tube assembly enclosure. Enclosed, group-operated disconnecting switches, suitably key-interlocked with tube enclosure doors and high voltage power circuit breakers are provided to insure safety.

Switching of the auxiliary and ignition transformers to high voltage lines is accomplished by horn gap disconnecting switches, key-interlocked with the transformer secondary air breakers to prevent their operation under load. The auxiliary transformers are protected by suitable current limiting fuses. Manually operated, low voltage air breakers provide means of segregating the radial feeders and cross tying between transformers

Figure 10 — Cross-section elevation of the 20,000 kw electronic converter station of the Carnegie-Illinois Steel Corporation.



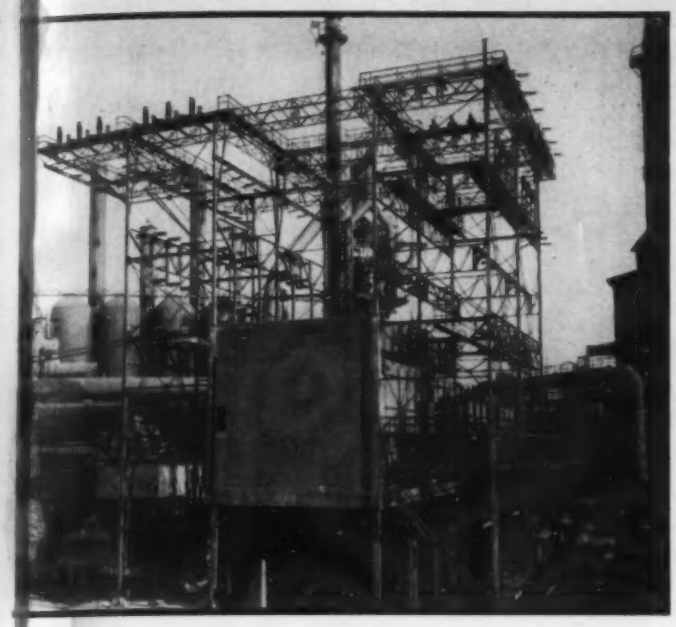


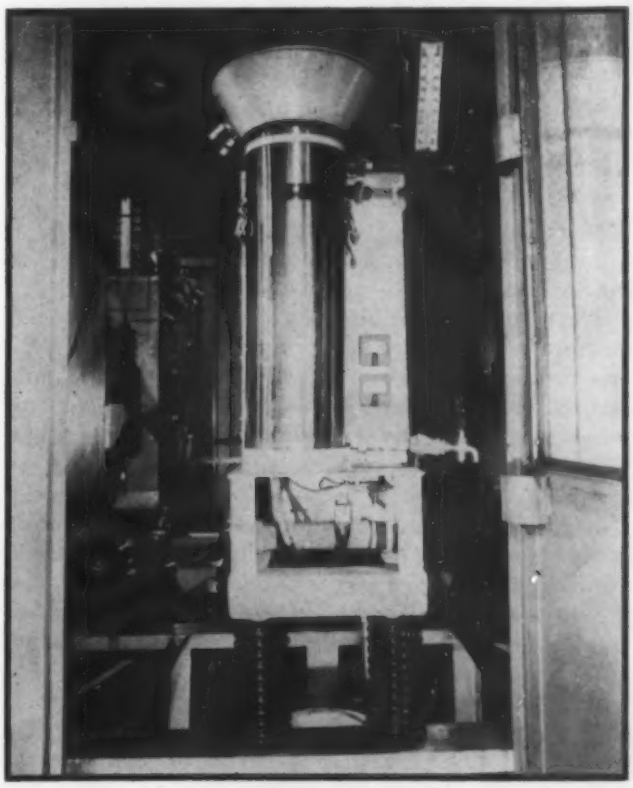
Figure 11 — Two 10,000 kw Electronic power converters and control installed in brick housing; 60 cycle switching and lines at left, 25 cycle switching and lines at right of structure. (above left)

▲

Figure 12 — Converter tube assembly enclosures for rectifiers-inverters (view through center isle). (above right)

▲

Figure 13 — Twelve-tube electronic converter enclosure (interior view). At center, a rectifier-inverter tube mounted in front of grid control equipment on insulated platform. Additional grid control at left rear. Excitation insulating transformer below. (below)



of similar frequency in case one of the transformers is out of service for any reason.

Load Control — The converter is basically under automatic current control at all times. The operator has a choice of three types of control: manual, by control switch which merely adjusts the calibration of the current regulator to constant current values; next, automatic watt regulator control which holds constant watts by modifying the current regulator; and lastly by a demand regulator. The direction of power flow is selected by the operator for manual or watt regulator control, but becomes automatic under demand regulator control. The magnitude of power flow through the frequency changer is determined by the magnitude of the reference voltage used in the field circuits of the control amplidyne generator associated with the firing circuit, (Figure 16). The reference voltage is obtained from an induction regulator, which determines, by rotor position, the magnitude of that voltage. Driving power for the shaft of the induction regulator, selsyn and cam-operated position switches is obtained from a d-c motor, whose armature is energized by an amplidyne generator, which gives the advantages of reversible rotation without the use of reversing contactors, easy adjustment of motor armature voltage magnitude and easy adoption of control circuit and inherent dynamic braking. The low control field current of the amplidyne permits the use of relay and control switch contacts directly in the field circuit. The contacts of the cam-operated position switch prevent closing of the breakers except when the induction voltage regulator is in a zero power flow position, when all tubes operate as inverters.

The demand regulator is an indicating-integrating device which measures the interchange of power between the public utility system and the steel company's 60 cycle system. The regulator is designed to hold a preselected value of instantaneous exchange kilowatts. This value is, however, corrected to compensate for any differential between the ideal preselected kilowatt hour exchange and the actual kilowatt hour exchange, as time progresses.

Protective Relaying — Protective relaying is included

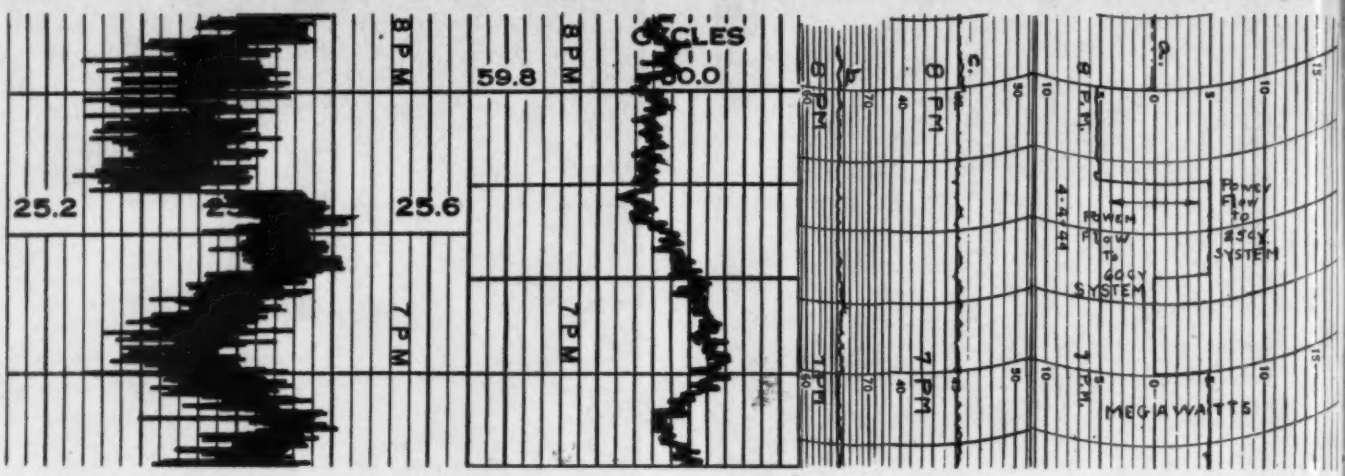


Figure 14 — Charts illustrating effects of manually resetting of automatic constant power control including power reversal.

a. Changes in load by manually adjusting kw regulator for constant load to 25 cycle system, zero load, and reversing direction to supply load to 60 cycle system.
b. 69 kv 60 cycle system voltage.
c. 44 kv 25 cycle system voltage.
d. 69 kv 60 cycle system frequency.
e. 44 kv 25 cycle system frequency.

in the switchgear which is mounted on the first floor of the two-story building (Figure 17). Faults which must be considered are classified as follows:

1. Faults associated with the converter, its transformers and auxiliary apparatus.
   (a) Insulation failures in the transformer and a-c system.
   (b) Mal-function of the tubes or insulation failure in the d-c conductor system accompanied by failure or too frequent operation of the automatic fault suppression features of the converter grid and ignition control.
2. Faults associated with the power systems.
   (a) Short circuits.
   (b) Loss of voltage.

As it is impractical to apply differential relays to rectifier transformers by reason of the complexity of their secondary windings and the character of the current flowing in these windings, the most applicable protective relay is the short time delay, induction, overcurrent relay with an inverse characteristic. It has sufficient time delay to allow for normal transformer magnetizing inrush currents and short duration fault currents resulting from transient disturbances in the tubes.

The type of fault peculiar to a rectifier has been termed an "arc-back" which is the failure of a rectifier tube to hold off negative-anode-cathode voltage during the inverse part of the cycle. When a tube arcs back, a cathode spot is formed on the anode with the result that the rectifier tube will carry current in the reverse direction. It looses its rectifying properties for the duration of the arc-back.

The characteristic fault of an inverter produces a short circuit in the d-c link, whether it be because of a tube failure, a mis-fire or insufficient deionization time.

Figure 15 — High tension voltage and current oscillograms of electronic converter operating with power flowing from 60 cycle to 25 cycle.

A— 25 cycle voltage, one 10,000 kw inverter operating 12-phase.

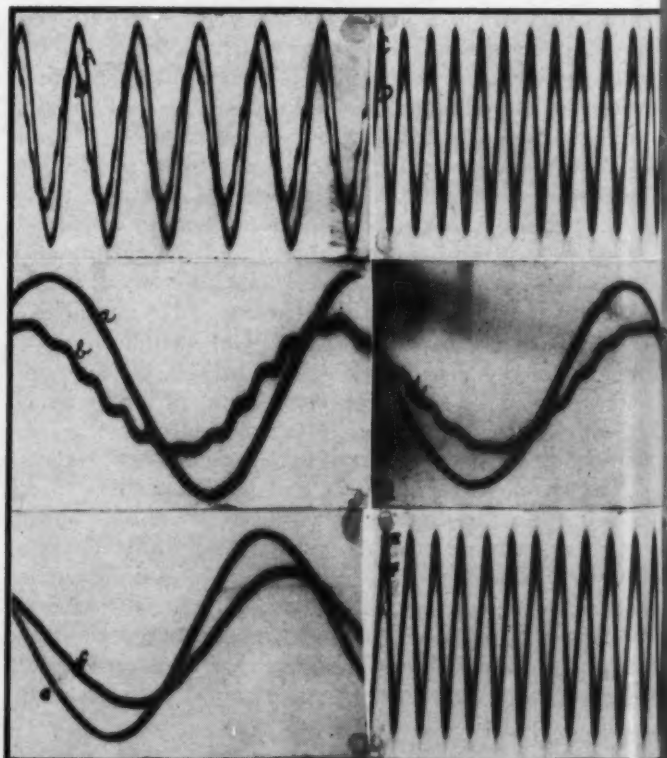
B — 25 cycle current, one 10,000 kw inverter operating 12 phase.

C — 60 cycle voltage, one 10,000 kw rectifier operating 12-phase

D — 60 cycle current, one 10,000 kw rectifier operating 12-phase.

E — 60 cycle voltage, two 10,000 kw rectifiers operating 24-phase.

F — 60 cycle current, two 10,000 kw rectifiers operating 24-phase.
a, b, c, d, e, f, designate the same waves as A, B, C, D, E, F except taken with a slower film speed.



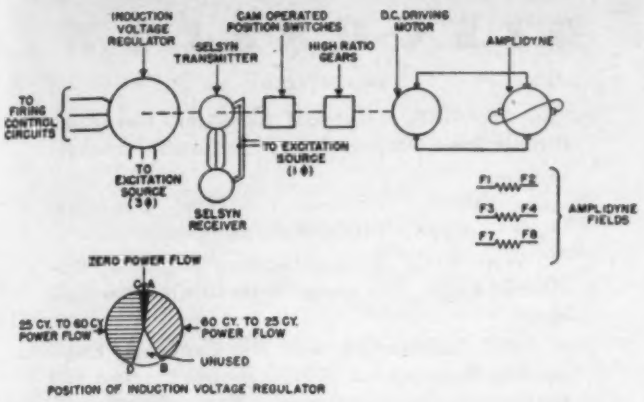


Figure 16 — Control device for power flow through the power converter.

The inverter will continue to try to commutate the d-c short circuit current and when this current drops to a normal load value, the inverter will be able to commutate the current and resume operation. This type of fault is generally called a "shoot-through."

It is possible to relieve either the rectifier or the inverter from characteristic electronic faults by blocking the ignitor. Operation can be resumed if the faults are not persistent. When suppression goes into effect, as indicated by tube fault currents, all tubes have their ignitors blocked, thereby preventing those tubes which are in fault from continuing the fault. The duration of blocking is sufficiently long to enable the tube which arcs back or fails to fire properly to regain control. Depending upon which frequency system is at fault, it requires only 4/10th to 4/100th second to resume operation from initiation of fault.

Both rectifier arc-back and inverter commutation failures cause high currents in the rectifier circuits and a-c supply lines feeding the rectifier. Inverter commutation failures also draw some short circuit current from the receiving system. The control of tube failures is known as arc suppression, and it reduces the rectifier a-c and d-c currents to zero in a small fraction of a second, whereupon the suppression is removed and operation is immediately resumed. This action is so fast that it is not necessary to disconnect the converter and restart the service later as is common with conventional low voltage power rectifiers.

Should the tube failures or failure in the d-c circuit persist, the fault suppression equipment opens both main line circuit breakers after a preselected time duration.

Disturbances occurring in the supplying a-c system produce voltage dips, thus causing a reduction in power flow to the receiving system. Since the electronic tubes are uni-directional current devices, there will be no back feed to the supply system even though its voltage falls to zero. Power flow can reverse only when phase control is intentionally readjusted.

When the receiving system voltage drops because of system faults, but not enough to cause inverter commutation failure, there is a moderate increase in power output. The watt regulator restores the previous load within a few seconds, even if the lower voltage persists. If the receiving system voltage disturbance reduces the voltage so much that the increased load through the converter causes commutation failure, delivery of power from the converter will stop. Therefore, inverters do not feed excessive currents to the receiving system faults. By this action, they do not, of themselves, assist in maintaining system voltage for heavy load changes or disturbances, yet the synchronous capacity required for their excitation does tend to support system voltage. Provided system faults are cleared by circuit breakers within one to three seconds, the converter will fully protect itself by means of its own internal "arc suppression" control and its power circuit breakers may remain closed.

THE FUTURE OF ELECTRONIC POWER CONVERTERS

Again using "electronic power converter" to broadly classify all forms of equipment which convert power to one characteristic into power of a distinctly different characteristic by means of electronic tubes, it is well known that the power rectifier has firmly established itself by means of its desirable characteristics in converting alternating to direct current.

Figure 17 — Control room panels and excitation cubicles

For the electronic converter which involves conversion from a-c to a-c, the future outlook is toward those opportunities in which the characteristics of the electronic equipment are particularly adapted to the circumstances.

As a frequency changer or as a connecting link between systems of the same frequency, the electronic equipment has some attractive advantages and some disadvantages. Its disadvantages are chiefly those associated with its deficiency in supporting system voltages, its cost, as compared to an overhead line used as a link between systems of like frequency and its deficiency, not only in being able to furnish over-excited reactive current to either system, but the necessity for the two systems to supply over-excited reactive current to the frequency changer.

The synchronous and Scherbius types of rotating converters have the ability to supply and control over-excited reactive current to the systems to which they

are connected. These same types can furnish power to independent inductive or capacitive loads. All rotating types of frequency converters are sources of short circuit current, the system being relieved of the fault in the opening time of conventional circuit breakers. Rotating types of frequency changers resist a change in voltage due to disturbances, and are, consequently, a factor in improving the voltage and the stability of a system.

The efficiency of the electronic frequency changer is well maintained throughout its load range and is relatively higher than that of rotating frequency changers. Losses associated with the supply of over-excited reactive kva for commutation, etc. vary with each case and tend to increase the losses chargeable to the electronic frequency changer.

Reactive kva must be furnished to the electronic frequency changer when it is in parallel with synchronous generation, or when it is supplying an isolated load. Reactive kva of the load must also be supplied by suitable means. Voltage regulation of a frequency changer supplying an isolated load rests solely upon a condenser which must be available for this purpose and must be started from some source other than the frequency changer. When these conditions are satisfied, and only then, stub-feed from an electronic frequency changer seems entirely feasible.

The ease and rapidity with which loads through an electronic frequency changer can be controlled and made responsive to a number of different elementary signals has been well exemplified in this installation. Weights, dimensions and foundations of the equipment immediately involved in converting power from one system to another of different frequency are less for the electronic frequency changer, (excluding those elements contributed by the synchronous equipment required for commutation, etc.,) than for the rotating frequency changer. Transformers are required by the electronic converter to insulate d-c from a-c systems and to obtain multiphase operation from the three-phase system. This addition can generally be expected to increase the weight and dimensions of the complete electronic frequency changer above those for the rotating equipment. Foundation dimensions will vary with the particular location. Where both types of converters require transformers to raise potentials above those which can be withstood by rotating frequency changers, these physical factors will be in favor of the electronic frequency changer.

It is not the intention of the authors of this paper to advocate the application of electronic frequency changers for all cases of system interconnection, but to point out that a useful tool has come on the market that may be more applicable in certain instances than conventional methods previously available.

One of the fields in which it seems possible that the electronic frequency changer may find itself useful is that in which the receiving system frequency must be readily and widely varied. Considerable development must need to be done before such a variable frequency changer can be offered to the trade.

In the meantime the installation at the Carnegie-Illinois Steel Corporation plant is proving itself useful in every-day service.

DISCUSSION

PRESENTED BY

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J. H. COX, Section Engineer, A-c Generator Engineering Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

W. E. GUTZWILLER, Rectifier Division, Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin.

F. O. SCHNURE, Electrical Superintendent, Bethlehem Steel Company, Sparrows Point, Maryland.

A. G. DARLING, Industrial Power Section, Industrial Engineering Division, General Electric Company, Schenectady, New York.

F. W. Cramer: The Carnegie-Illinois Steel Corporation operates three large 25 cycle power systems: one in the Chicago district with a generating capacity of 297,800 kw, another in the Pittsburgh district with a generating capacity of 138,000 kw and a third in the Youngstown district with a generating capacity of 47,200 kw. There is also a 60 cycle generation of 50,000 kw in Pittsburgh.

Since these systems supply steel mill loads, a close control of voltage and frequency as practiced by utilities is not required, and variation in frequency from 22½ to 26 cycles due to sudden load swings, or a drop in voltage of 10 per cent does not interfere with operations.

In the Chicago district, Gary Sheet and Tin Mill's wide strip operation was installed in 1936 using 60 cycle equipment with a load demand of about 42,000 kw. The power is purchased from the public utility company. This 60 cycle load has since been increased as new equipment was placed in operation and 60 cycle power is gradually replacing 25 cycle power in this area.

In 1940, studies were made in the Chicago district on possible methods for interconnecting the 25 cycle system with its wide variations in frequency and voltage to the utility 60 cycle system with practically constant voltage and frequency conditions, and have power feed either way.

These studies indicated that the mercury arc rectifier and inverter combination, where frequency variations would be eliminated in the d-c tie, could be used and a 6667 kw unit was purchased. The war emergency handicapped the development of this project and delayed completion of the unit.

In the Pittsburgh district the Irvin works, installed in 1938 together with the Edgar Thomson slabbing mill operation, were designed as 60 cycle plants and the power — about 45,000 kw — purchased from the public utility company.

In 1941, when the emergency expansion program was authorized, the electric furnaces at Duquesne works and the blast furnaces at Edgar Thomson were designed for 60 cycle power.

The additional blast furnaces at Edgar Thomson works produce enough gas for steam production over and above all other requirements to generate 50,000 kw, and if it is not used for this purpose, would be wasted. Two 25,000 kw, 60 cycle turbo-generators were installed to utilize this available waste fuel. This, however, did not solve the power problem for the open hearth, slabbing mill, 160 in. plate mill and forge shop project located in the Homestead works, which project is located in a 25 cycle area near modern mills with 25 cycle main drive motors. The topography of the country plus lack of space on mill property made a 60 cycle high tension line a costly project with complications of dual transmission systems. Studies on this problem indicated that the 50,000 kw produced by the 60 cycle turbines would about balance the additional electric load created by the three new projects, and if a frequency converter could be installed the 20,000 kw, 25 cycle load in the new Homestead project could be served from those turbines.

As in the Chicago district, means for this frequency conversion were studied and propositions requested on both electronic and rotating equipment. The cost installed for a 20,000 kw electronic unit without foundations or building was $50,000 greater than for a rotating unit. However, the main unit for a Scherbius set weighed 715,000 lb, and for a Kramer unit 507,000 lb plus two rotary converters at 76,000 lb each. Either type of rotating unit would require a 50-ton crane to handle the heaviest piece. The total weight of the 48 units comprising the electronic converters was 135,000 lb, and they could be installed without foundations on a floor designed for a load of 150 psi. The location for this unit is in the flood area, so that the floor level for equipment must be 12 ft above ground level. This made the heavy foundations for rotating equipment more expensive.

When the total cost of the project, including building, foundations, crane, steel work and ventilating system for the rotating equipment, was compared to the similar total cost for electronic equipment, there was considerable savings in favor of the electronic. There was also the benefit of having two complete units in the electronic project.

The delivery of the electronic equipment was given as 427 days compared with 650 days for the rotating and the quantity of critical materials involved was considerably less.

The efficiency of the electronic unit operating at a monthly load factor of 50 per cent should be about 5 per cent better than the rotating unit which, on 100,000,000 kwh per year, would mean a savings of 5,000,000 kwhr. This saving at $.005 per kwhr equals $25,000 annually.

The overall efficiency, 69 kv 60 cycles to 44 kv 25 cycles, has been 94.88 per cent.

As for operating costs, it will require several years to obtain an average value. A tube life of five years is expected. Other than tube replacements, repair costs should be very minor.

B. M. Jones: The Duquesne Light Company 60 cycle system and the Carnegie-Illinois Steel Corporation 60 cycle system now operate in parallel, and the converters which tie the steel corporation's 60 cycle and 25 cycle systems also tie the Duquesne Light 60 cycle system to the 25 cycle system of the steel corporation.

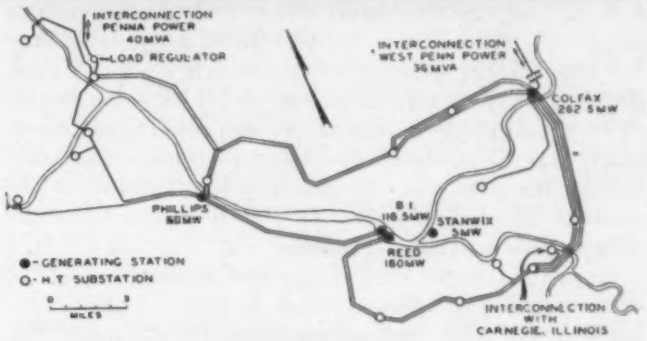

Figure 1 — Map showing public utility system with interconnection to steel company's system indicated at lower right.

Figure 1 shows the Duquesne Light system diagram, and the steel corporation interconnection is shown in the lower right near a bend in the river. The 60 cycle load of the steel corporation carried on our system before these electronic converters were installed has been as much as 60,000 to 70,000 kw at times. The total installed nameplate generating capacity of Duquesne Light is 624,000 kw, with 262,500 kw at Colfax, 180,000 kw at Reed, 116,500 kw at Brunot Island, 60,000 kw at Phillips, and 5000 kw at Stanwix. Phillips is our newest plant, having been placed in service in January, 1943. It was planned and authorized prior to our country's entry into the war, in anticipation of the large war loads to come, and which actually did come, and we take pride in this advance planning.

We are very glad to state that these devices are not causing any concern or disturbances at the present time. Some interference did occur on the Duquesne Light system at the time of initially placing the first 10,000 kw converter in service in December, 1943, resulting in rather widespread voltage flicker complaints on our system which, we believe, resulted from sporadic faulty tube operation (commutation failures) which lasted intermittently from the time the original cut-in was made at about 9 P.M., throughout that night, the next day, and, to a lesser extent, spasmodically thereafter. Since that time, the second 10,000 kw unit has been cut in service (on February 15, 1944), and some voltage complaints were encountered, although there were not as many as when the first unit was cut in.

It is interesting to note that the electronic frequency converter installation requires each system to provide its own reactive, for the converter installation itself does not do this. The frequency records for our system during the time these frequency changer installations have been in service and during the initial tryout thereof show no appreciable effect of this interconnection.

One attractive feature of such a frequency converter tying two large systems together is the steady load that can be interchanged between the two systems, as has been referred to by the authors. The ideal condition of

an electric interconnection is for the power flowing over the interconnection to be at absolutely steady load. This same condition is desirable for any load, but the fluctuating nature of most loads is inherent and unavoidable.

Another interesting feature, which is very desirable to us, is the fact that under fault conditions on either system, the electric converter prevents excessive flow of current and actually limits it to slightly more than full load. A big interconnection which does not limit the flow of short circuit as this does, imposes greater short circuit duty on equipment and could easily cause much expense in circuit breaker replacements, in addition to the possibility of affecting the stability of the systems. These electronic converters eliminate these two difficult and expensive problems.

Even for ties between systems of approximately the same frequency, the degree of control of the power between the two systems obtained by electronic frequency converter installations would be a distinct advantage in some cases, although modern steam turbine governors and load controls make interconnections between systems very practical and have in recent years minimized the degree of power swings over such connections. Even so, there might be installations requiring a smooth control of the flow over interconnections, and the engineers planning such interconnections should explore the possibilities and economic advantages of electronic frequency converters before arriving at their decision.

It is interesting to note that the converter handles fault currents, internal and external, and restores power under normal conditions after an elapsed time of not over 4/10ths seconds after fault release, thus reducing fault damage, duty and stresses on equipment and circuit breakers below extents created by corresponding size rotating equipment. This is of particular interest to the Relay Protection Engineers, and is more important to such engineers for a large power system. It is particularly interesting to engineers applying circuit breakers and to those concerned with the stability of the generators.

The Duquesne Light has been operating in parallel with adjacent power systems, the West Penn Power Company and Pennsylvania Power Company, since about 1925, and such interconnections are still in satisfactory service. Several years ago we installed a regulating transformer in one of the interconnections to permit the parallel operation of our system with both these interconnections simultaneously and to control the flow of power reasonably close (within steps of 2000 kw more or less) over the tie with the Pennsylvania Power Company. In our case, each interconnection above one requires a regulating device to control the flow of power so that it will not flow into our system from one interconnection and out over the other one, the regulating transformer being set to make the second interconnection feed into our system. Of course, rapid load swings cannot be controlled by this regulator.

Investigations and research have been made jointly with the steel corporation to compare the 60 cycle voltage with the flicker in it caused by forced commutation failures with a standard 60 cycle laboratory wave to determine the magnitude of the fluctuating voltage. The results seem to indicate that the voltage fluctuation at the connecting point between the 60 cycle systems of Duquesne Light and the steel corporation was in the order of 4 to 5 rms volts for staged commutation failures. These deviations were observed on a cathode ray oscillograph, and photographic records were obtained. Varying reports were received from previously informed observers. Some could not even discern the flicker; most of them did but did not consider it objectionable, although the fluctuations were not nearly as prolonged during the test as when the units were first placed in service. The two tests were of very short duration (about 5 or 6 seconds each) and continued flicker of this magnitude would have been objectionable to many; certainly it was during the first stages of the operation of the sets. The test fluctuations occurred at the rate of 1.5 per second, which is approaching the most critical frequency for visual perception and objection.

E. R. Whitehead: Various methods have been suggested for the measurement of so-called "flicker voltage" in the field. The term "flicker voltage" usually refers to voltage disturbances having a definite frequency and approximately the same amplitude, such as those caused by "stitch" welders.

The measurement of disturbances occurring at random and having neither fixed frequency nor amplitude is most satisfactorily accomplished oscillographically.

It was decided to compare the 66 kv bus potential at the interconnecting substation with that of a stable standard source furnished by a sine wave generator at the utility standardizing laboratory.

For convenience, both voltages were brought to the office of the system operator over telephone lines where the oscilloscope and resistance voltage dividers were connected as shown in Figure 1. The slight phase shift

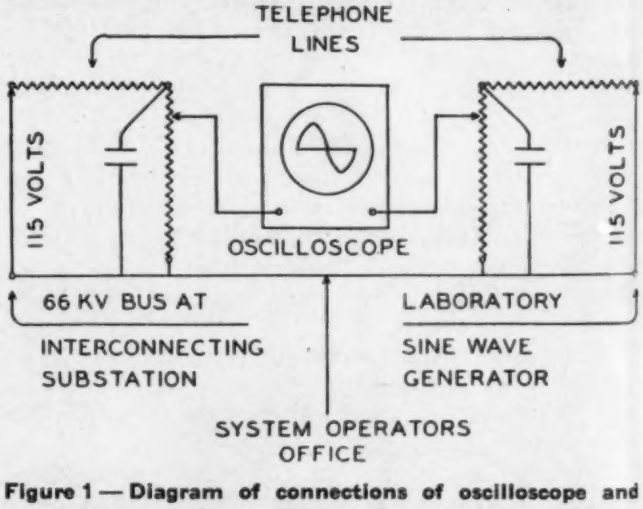

Figure 1 — Diagram of connections of oscilloscope and resistance voltage dividers for measuring "flicker voltage."

caused by the capacitance of the telephone lines was compensated by adjusting the stator position of the sine wave generator, while accurate magnitude balance was obtained by the voltage dividers. In this way perfect fundamental frequency balance was achieved, leaving about one half volt harmonic unbalance which was blanked out on the oscilloscope screen. The zero line

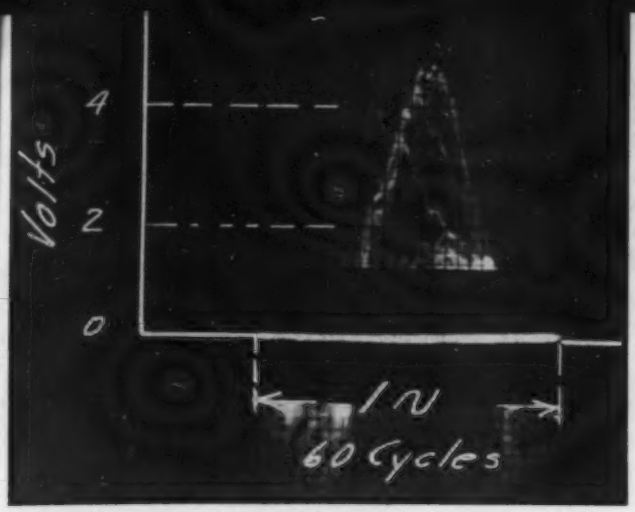

Figure 2 — Oscilloscope record from test. Scale is in rms volts.

was obtained by leaving a narrow slit in the blanking paper.

Figure 2 shows one of a group of records obtained during a series of staged tests in which electronic faults were artificially produced in the frequency converter. The scale marking is a calibration in rms volts made by depressing the voltage at the interconnecting station in accurate two-volt steps. This record shows eight fluctuations, which occurred in five seconds. The time intervals were measured from a high speed ammeter chart.

J. H. Cox: The authors have presented a description of a most interesting engineering project capably executed. This is a good example of the trend in the utilization of electronics in ever broader fields.

As is quite natural, the authors of this paper have presented the favorable side of the picture and I am afraid that this, together with the excellent engineering performance, may be somewhat misleading and indicate that high power electronic frequency changers are now ready for general application. Although reluctant to criticize a good job, I would like to emphasize the adverse side of the picture.

Some of the important features, although covered in the paper, seem to justify emphasis. The most valuable feature of the electronic frequency converter is the variable frequency ratio. This feature removes the sometimes prohibitive requirement of tying the frequencies of two a-c power systems rigidly together. Less important attractions are extreme ease and flexibility of control and absence of noise and vibration. Against these attractions must be weighed the following disadvantages:

(a) A present high initial cost. (The cost of upkeep can hardly be estimated until the life of the relatively expensive tubes is established.)
(b) Adverse power factor and harmonics.
(c) Low overload current limits.
(d) Complicated control and protection circuits.
(e) Inability to supply isolated loads without a further considerable increase in complication.

An electronic frequency converter transmits only kilowatts and contributes nothing to the reactive kva requirements of either power system. This would not be so serious, but the converter itself requires additional reactive kva for its own operation, particularly on the inverter or receiving system, and this requirement is really relatively large.

This requirement for reactive kva is related to the more serious limitation in overload current. For a given setting of inverter operating angle there is a definite limit in the current that can be supplied by the inverter without failure, even though the tubes perform perfectly. Unfortunately the higher the setting for overload the greater becomes the required reactive kva during continuous normal operation. Also, variations in the voltage of the inverter, or receiving, system have a profound influence on this overload current limit. As described in the papers, the converter will not supply an isolated load, unless equipped with a considerable increase in apparatus and complication, or by a considerably different basic circuit.

I would like to ask if it proved equally satisfactory to operate the frequency changer to take load peaks, as to operate at constant load. Is the latter method of operation desired, or is it a limitation of the equipment?

W. E. Gutzwiller: The paper gives an interesting and complete description of the equipment, the installation and the early commercial operacial operation of the two 10,000 kw electronic frequency changer sets installed at the Edgar Thomson works of the Carnegie-Illinois Steel Corporation at Braddock, Pennsylvania. The authors are to be commended on the very complete manner in which they presented the subject and particularly, the way they pointed out the advantages and disadvantages of this new electronic frequency changer equipment in contrast to the more conventional rotating type converters.

For the sake of completeness of records, it should be stated that other manufacturers of power electronic equipment in this country and abroad have also contributed to the development of this electronic type converter. In Europe, mercury pool type electronic power inverters in various forms have been used since 1934 and in unit capacities from approximately 2000 kw to 3000 kw. A 25/60-cycle electronic frequency changer of two-thirds the unit capacity of the one described in the foregoing paper was built and put in commercial service in September, 1943 in one of the mid-western mills of the Carnegie-Illinois Steel Corporation and has been used for power demand control ever since. This unit, while performing a very similar service as the one in the Pittsburgh area, uses somewhat different type of equipment and circuits. The electronic units are of the pump evacuated type in contrast to the sealed tubes described in the paper. However, a d-c link between two separate electronic units is likewise provided and power conversion is in both directions.

With two large-scale commercial installations made in this country this new electronic power conversion tool has now definitely passed the laboratory stage and should find many new uses in the near future, one of which undoubtedly will be its application in connection with long distance transmission of high voltage direct-current power.

The electrical manufacturers and the electric power industry as a whole are thankful to the management and engineers of the Carnegie-Illinois Steel Corporation who, through their pioneering spirit and splendid cooperation have made possible these first two full scale converter installations.

F. O. Schnure: In the description of this installation it is very interesting to have the author's frank discussion of the advantages and the disadvantages of the electronic power converter when used as a frequency changer. Having been concerned with the operation of a 20,000 kw synchronous type of rotating frequency changer for a number of years, which has been found to be very dependable, I would be reluctant to exchange it for an electronic converter that would not be able to regulate the voltage or be instantly available for the exchange of power in either direction. This last characteristic has saved our plant several outages.

On the other hand, several years' operation of an a-c to d-c electronic power converter has provided us with an appreciation of how easily and rapidly it responds to the requirements of the job on which it is applied. Its higher efficiency is also a feature that favors the electronic over the rotating converter.

The electrical industry owes a vote of thanks to both the builder and the user for their pioneering in this installation.

F. W. Cramer: Is it correct that your Sparrows Point power system has ties with the utility on both the 25 and 60 cycle systems?

F. O. Schnure: Yes, it has.

F. W. Cramer: Then you would not have the wide variations in frequency that occur in isolated plants.

F. O. Schnure: No, we are tied in with the 37,000 kva on the 25 cycle side, and 60,000 kva on the 60 cycle side, and our own power generation is 50,000. The 25 cycle and 60 cycle systems on the power company side are tied together with several frequency changers, two 35,000 kw units in Baltimore and a smaller unit at Holtwood. They, of course, hold the two systems very closely in step. We have no trouble in that respect. The only thing we do have to watch is that when they change their frequency changers, load them either toward the 25 or the 60 cycle end, we also have to change ours.

A. G. Darling: The discussions presented have, in general, contributed either additional information or given valuable and constructive criticism, so enhancing the value of the material presented in the papers.

Since one of the authors was also one of the men who investigated frequency changers and selected the electronic type, the paper could not quite say all that the other two authors would like to have said, but the other two authors give due credit to the integrity and the sincerity with which the Carnegie-Illinois Steel Corporation engineers, led by Mr. F. W. Cramer, made such a thorough investigation of various types of frequency changers for the particular installations to which Mr. Cramer referred.

Mr. Cramer had added much valuable background information leading to the selection of the electronic frequency changer and contributed interesting results of operation.

B. M. Jones' and E. R. Whitehead's presentations of the effects of the frequency changer upon the operation of the Duquesne Light Company shows how little the effect of the converter can be noticed, since the period of initial adjustment. It can be assumed that the reactive kva required by the converter is supplied by the steel company.

The tests reported by Mr. Whitehead necessitated the converter be intentionally forced into electronic fault conditions. The slight voltage fluctuations which occurred in five seconds were due to the operator's wish to be certain that the faults were sufficient to be observed. Normally, only a single fault occurs which is cleared by the fault suppression control. Electronic faults are evidently not a cause of noticeable system voltage disturbance and single faults do not cause customer reaction.

Mr. Whitehead is to be complimented on the ingenious and accurate method used in making these interesting tests which contribute valuable information to the project.

Mr. Whitehead pointed out that the maximum disturbance was five volts. I would like to ask him if that is not an instantaneous value of voltage difference between the true sine wave generator at constant voltage and the fluctuations caused by the electronic disturbances, or whether it is an rms value?

E. R. Whitehead: The difference was an rms value.

A. G. Darling: Mr. Cox has chosen to emphasize what, in his opinion, he believes are disadvantages without attempting to draw a balance with the advantages. Points brought out in the paper and discussion will serve to clarify Mr. Cox's remarks:

a. Mr. Cramer has, in his discussion, given data which pertains to initial cost and upkeep.
b. It has been pointed out in the paper that the reactive required by the converter represents a charge against this type of unit. Once this is recognized and evaluated, it becomes a tangible factor and can be equated against advantages.

The question of adverse harmonics has been duly answered by Messrs. King and Kent at the A. I. E. E. meeting, St. Louis, Missouri, June 1944, as a result of their American Telephone and Telegraph and Edison Electric Institute tests insofar as telephone interference is concerned. They reported that there is no noticeable interference.

c. Low overload current limits are mentioned as a characteristic of the electronic frequency changer. Assuming Mr. Cox has the characteristics of rotating frequency changers in mind as a reference, a direct comparison will show that the electronic equipment, has, in this case, a 125 per cent two hour and 200 per cent one minute load rating. Other designs could be rated for 200 per cent load for one minute, even though not given a 125 per cent two hour rating. These ratings are equal to or higher than standard for rotating frequency changers.

Maximum loads, not generally included in ratings, and in excess of one minute ratings, can be withstood by both the electronic and rotating frequency changers when under regulator control. The maximum pullout torque of a conventional rotating converter and the maximum load of an electronic converter are in the same order of magnitude, assuming both are under regulator control and that the system voltages are normal. In the case of the Carnegie installation, when the inverter angle is fixed at a value corresponding to the maximum expected spread in system voltage ratio and when the rectifier angle is under automatic load control, the electronic frequency changer will develop 2.6 times normal lead. When synchronous machines are called upon to deliver maximum kw loads under

ceiling excitation from normal excitation systems, their ability to furnish overexcited reactive kva is diminished. When the electronic converter is supplying an overload, it draws more underexcited reactive kva from the systems.

If Mr. Cox is loosely using the term low overload limits to mean low available short circuit current, the question might be raised as to whether high short circuit current from a frequency changer is an advantage, considering the likelihood that it will be only one of many sources of short circuit current and of voltage maintenance.

d. It is true that the control and protection of the electronic converter presents problems unusual to the designer familiar with rotating machine control. However, these problems were handled by men whose previous experience had been with conventional rotating machines and transformers. The designers of the control and protection circuits described in this paper testify in their A. I. E. E. paper that these features are both versatile and simple.

d. Mr. Cox charges the electronic converter with an inability to supply isolated loads without a further increase in complication. Experience in other instances, cited by Mr. Gutzwiller and tried out in experimental form by members of the author's organization, show that the additions needed are relatively simple because they are largely in the form of conventional synchronous condensers with starting motors and frequency sensitive relays.

The points brought out by Mr. Cox as limitations do not therefore represent unsolved problems. What is known to be, can be met with confidence.

Mr. Cox also asked if it proved equally satisfactory to operate the frequency changer to take peak loads as to operate at constant load. The demand regulator referred to in the paper, but not fully described because of limitation of time, was furnished to maintain a relatively constant load taken from the Duquesne Light Company by the steel company's 60 cycle system. The regulator has been left disconnected as it has been more essential to furnish constant power to the 25 cycle system than to limit purchased power peaks. In the future it is expected that the demand regulator will go into operation and may call upon the frequency changer to reverse its loads as the circumstances of load increase and decrease take place.

The comments given by Mr. Gutzwiller are very much appreciated. Having had some field experience with an electronic frequency changer, Mr. Gutzwiller is quick to sense advantages along with limitations. Due credit is given to all who have contributed to the early, as well as recent, development of the art.

Last spring when Mr. Schnure showed me his 25,000 kw rotating frequency changer in operation, it was apparent that much credit should be given to the Consolidated Edison Company of Baltimore and their engineer in charge of governors for the refinement of settings which resulted in no obvious interchange of power through the frequency changer and so, between systems. I am sure Mr. Schnure understands that voltage regulation of an electronic converter as well as that of a rotating converter is dependent on an excitation system. For the electronic equipment, the excitation system consists of separately excited synchronous capacity which tends to stabilize system voltage. For the rotating synchronous equipment, the excitation system consists of a separate exciter also tending to maintain system voltage. The electronic equipment, under system disturbances, continues to furnish power until its voltage is reduced to the limit of commutation. When the disturbance is relieved and voltage rises, the electronic equipment restores power to the system. Comparatively, the synchronous frequency changer, under system disturbances, continued to furnish current at all voltage levels and so tends to stabilize the system.

Stone DISCUSSION

(*Continued from page 47*)

rolls must run 5 per cent slower than the second set of rolls, and this relation must be maintained all the way from standstill to the running speed of some 3000 fpm. It is obvious that a very small variation in the relative speed means a very great error in the percentage elongation obtained. Suppose, for instance, a 2 per cent elongation was desired, and that the accuracy was only ¼ of 1 per cent. This error would mean a 12½ per cent variation from the desired elongation. Thus, the very fundamental of operation of this mill is dependent upon the accuracy of the speed control of these two sets of rolls. This job is entrusted to an electronic amplidyne system of control which has performed quite satisfactorily in actual practice.

The feed reel is driven by two 25 kw, 400/1600 rpm drag generators; the entry puller No. 1 by a 50 kw, 300/600 rpm generator; the entry puller No. 2 by a 100 kw, 300/600 rpm generator; stand No. 1 by a double armature 250 hp, 250/500 rpm drag generator; stand No. 2 by a 1500 hp, 300/500 rpm motor; delivery puller No. 1 by a 300 hp, 300/600 rpm motor; delivery puller No. 2 by a 150 hp, 300/600 rpm motor; and the tension reel by a 150 hp, 150/600 rpm motor. Power is supplied by a 1250 kw synchronous motor-generator set.

The feed reel, entry and delivery pullers, and tension reel are equipped with amplidyne type current regulators, and the No. 1 stand motor by an electronic amplidyne speed regulator.

This drive represents the most intricate equipment which has been built so far. There are 42 machines used in connection with the main drives, in addition to those used for auxiliaries.

The operation of this mill has been very satisfactory, and it is believed that this type of drive will have a prominent place in future temper mills.

C. A. Kral: This is an extremely interesting mill. After this war is over, we will naturally be faced with production of lighter base weights with higher tempers. From what I hear of the work this mill is doing, it will certainly be worthy of consideration for this future business.

M. D. Stone: In agreeing with Mr. Mohler, I wish to emphasize that accuracy of electrical control is of prime importance in the proper operation of the Uni-temper mill — and that the electrical system that was worked out has proved entirely adequate. It has enabled us to retain flexibility of operation together with relative speed control accuracy; we might otherwise have been forced to a mechanical drive.

THE *Accelerated* COOLING OF *Cast Steels*

. . . . discussing the effects of rapid chilling of cast steel and presenting a method of attaining these results in the manufacture of cast steel rolls . . . .

by J. M. DUGAN AND **G. D. GRIFFITHS**
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LIMA, OHIO

▲ BY way of introduction, it is perhaps wise to explain that it is not the intention of this paper to present technical data of which the accuracy is beyond question, nor to present theories which have not been hitherto the subject of many discussions. Rather, it is the purpose to review considerable technical information on the subject of accelerated solidification rates and through this review develop the reasoning process which brought about the development of a method for cooling roll castings through the solidification range with water. Nor do we feel that time is wasted in a discussion concerned only with generalizations about solidification rates because, apparently, that is still the extent of agreement in all the research work that has been done on this subject. However, in our own case and in the case of industry as a whole, the general conclusions which have been reached have been sufficient to indicate a general line of attack to the problems surrounding the manufacture of sound cast steel rolls.

Since we are presenting a method for drastic chilling of cast steels which cannot be subject to absolute scientific explanation, it might be well in our own defense to quote a few lines from the conclusion of a report of a committee of the British Iron and Steel Institute which conducted certain studies on the solidification rates of cast steels (Second Report on the Heterogeneity of Steel Ingots, 1928):

"It appears that even if a complete mathematical expression could be given to represent the freezing of the ingot in the mold, there would still be considerable doubt as to how to apply it until agreement is attained as to the best crystalline arrangement to aim for, and even then the influence of the rate of cooling, or of the velocity of freezing across the section, on that crystalline arrangement must be known. It is therefore clear that for the present the committee can well leave the matter as one requiring much further elucidation" . . . . this, after a study extending over a period of twenty-five years.

At any rate, mathematical accuracy is not a prerequisite to mechanical development in a practical manner. We feel that the results we have obtained, acting upon the assumptions which will be explained in this paper, indicate that we are at least headed in the right direction and we must leave the gaging of the extent of our progress until that time arrives when research work can show more quantative results.

We shall therefore try in this paper to bring out the general advantages which can be expected from rapidly cooled cast steels, according to the belief that is widely held in the industry. First, let us review the action of metal which is subjected to drastic cooling during the

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J. M. DUGAN

G. D. GRIFFITHS

solidification period. Since any type of chilling must of necessity be dependent upon the type of mold, our study should first consider the various steps which have brought us to the design of present-day molds.

As first used, no doubt, the only function intended for any mold was that it should provide a receptacle for the molten metal. Later, as the steel-making process became more refined, molds were so designed that they might perform additional functions, namely (1) to assist in the feeding of inaccessible sections, and (2) abstraction of heat so as to provide directional solidification. Later, in the design of molds more and more attention was given to the further function of producing sound castings. In the work of producing ingots, the study of molds has received its greatest impetus. To review the types of ingot molds and to discuss the types of steels produced with these molds would prolong this paper almost indefinitely. Since we are primarily concerned with a type or class of steel which is suited to roll manufacture, we will limit our discussion to the structure of steels in that class and to the type of equipment necessary to produce such steel. It is our belief that for molten steel cast in any ordinary type of mold the process of solidification is as follows:

As the molten metal at a temperature of approximately 2600 F comes in contact with the surface of the mold which has a temperature somewhere in the neighborhood of 200 F, there is an immediate chilling action upon the casting caused by conduction of heat through the mold which is in contact with the molten metal, and the resulting shock in the meeting of these two substances having such a great difference in temperature causes a thin skin of solid metal to form almost instantly. In an ordinary mold the transfer of heat from the molten metal to the mold causes a certain amount of expansion in the mold itself. Because the outer portion of the mold retains its lower temperature for a time after pouring, the expansion of the mold must be inwardly until all of the mold walls have become heated by conduction of heat from the molten metal. At this point the heat is removed from the exterior walls of the flask, being transferred to the surrounding atmosphere. By the time the mold and flask have become heated throughout, the interior surface of the mold has probably reached a temperature somewhere near that of the metal which has become solid around the outer rim of the roll casting. As soon as the mold and flask have become heated throughout, outward expansion of the mold begins, so that an air space forms between the casting and the interior mold wall, which space becomes an insulating area. However, this insulating effect is overcome in large measure by the radiation of heat from the casting to the mold walls, and after this point is reached the casting and mold cool together at approximately the same rate.

Before going any further with this discussion, we will attempt to show that metal solidifies in three distinct phases (Figure 6):

1. A definite chill area.
2. An area in which elongated crystals form due to the effect of any exterior cooling substance.
3. An area in which equiaxial crystals form in a manner common to molten steel which is allowed to cool slowly.

1. We now submit that the chill area can in no case be of very great thickness, nor is the thickness which can be expected from the use of one type of mold any greater than the thickness which can be provided by any other type of mold. Probably the only circumstance which can have any substantial effect upon the thickness of this chill layer is the difference between the temperature of the molten metal and the temperature of the mold itself. In other words, the thickness of the chill area depends entirely upon the degree of shock provided by the mold upon the molten metal.

2. Next, after the formation of the chill layer, comes the zone of elongated crystals which owe their design to whatever rate of cooling the mold in which they are cast can provide. Much has been done along this line in ingot production to develop molds which will produce steels having definite characteristics. Later in this paper we will discuss the types of molds which have been developed to produce sound steels as it is this class of steels which more closely compares with the type of steel from which rolls are made.

3. After that point is reached in the interior of the casting upon which the cooling action of the mold can have no further effect, a zone of irregular equiaxial crystals is set up. These crystals have a dendritic structure but they are arranged in no definite alignment. Since it is our belief that the chill area cannot be influenced to any great extent, we have directed our attentions to the nature of that second zone in the crystalline structure which we have labeled the rapidly cooled area. We

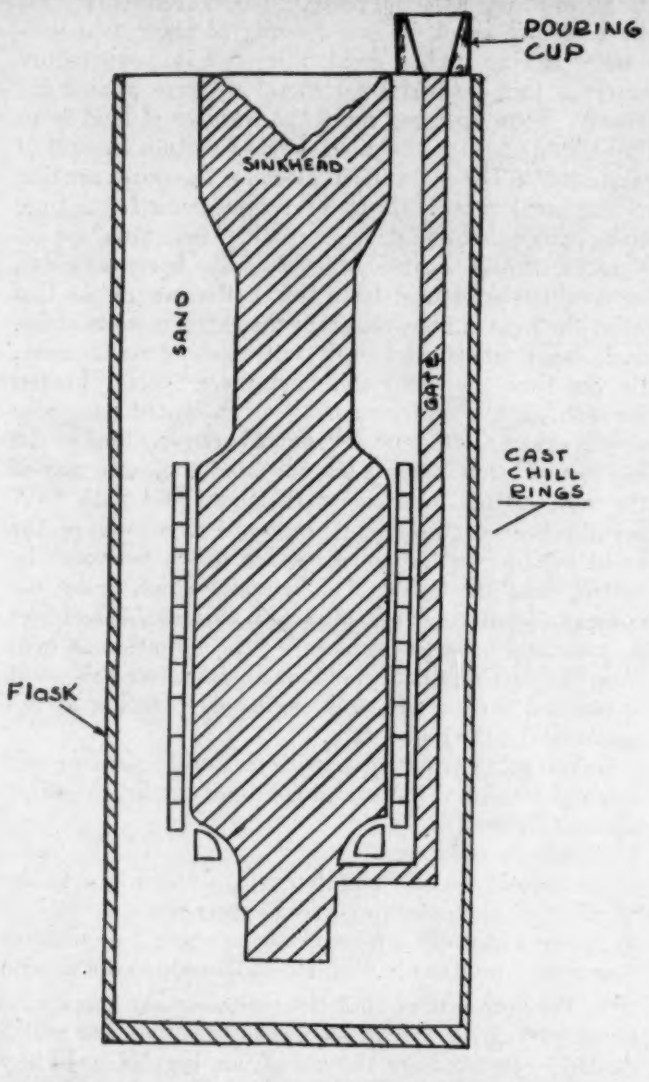


Figure 1 — Cross-sectional view of steel roll in mold, showing gate, cast chill rings ordinarily used for chilling body surfaces, and relative size of head necessary to feed this type of casting. (above)

Figure 2 — Pattern maker checking roll sweep. Steel roll molds are made by mounting a sweep cut out to the roll dimensions on a spindle and the mold cavity is actually "swept" or cut out as the spindle and sweep are revolved. (below left)

Figure 3 — General view of roll molding floor, showing molders cutting out molds with sweeps and applying silica wash to mold surface. (below right)

believe that the elongated crystals which form in this zone are dendritic in nature, as are all cast steel crystals; however, they are arranged in a columnar form which indicates the effect of the temperature-removing capacity of the mold.

Much has been written concerning the value of various types of grain structures in steel and it appears that there is little agreement as to what is the best type of steel for any particular use. Here again the discussion of various crystalline structures is beyond the scope of this paper. Too, the wide range in chemical analysis in which rolls may be cast means that many different crystalline structures result. However, it is our belief that there are many variables in steel structures of any given composition due mainly to differences in cooling rate, and further that, insofar as the section comprised of a dendritic or columnar group of crystals is composed of a compact association of crystals, that section is desirable and in all probability is the best type of steel from a standpoint of homogeneity. This homogeneity can be attributed to the manner in which the dendrites are formed. It is generally believed that dendrite crystals which are formed through a slow cooling process are heterogeneous chemically because that part of the crystal which is last to solidify has entered into a state of equilibrium, more or less, depending upon the rate of temperature change, with the molten metal in which it is forming, and, consequently, the analysis of the part of the crystal which forms last will be different from that part of the crystal which was first to form. Conversely, dendrites which are formed rapidly should not achieve a very great degree of equilibrium with the molten metal and consequently should preserve a greater degree of homogeneity.

To go back a few paragraphs, let us again consider the solidification process of a large steel casting through the three zones which we have enumerated (Figure 6). The first rapid chilling of the mold walls forms a thin layer of small equiaxial crystals along the surface of the casting. No doubt the interior side of this chill layer is minutely irregular, and these small irregularities provide the starting points for crystals of a dendritic nature to form. And so dendritic and columnar crystals will continue into the center of the casting for a distance equal to the heat-removing effect of the mold. It is our belief that the more rapidly this columnar crystal growth can be carried out the more homogeneous the steel in the outer portions of the casting will be.

According to Desch (Foundry Trade Journal, November 28, 1940): "When a solid solution solidifies, the solid which separated under conditions of equilibrium had a given composition. When solidification had gone further, the solid should be in equilibrium with a new liquid composition, but that could not take place unless the solid phase changed its composition by diffusion and a continuous process of diffusion was necessary for equilibrium. Under most conditions of cooling they would not get that perfect diffusion. Diffusion in the solid state was a slow process compared with freezing and therefore there was a lag between the freezing process and the adjustment of the solid to keep itself in equilibrium with the liquid."

Unless the process of diffusion in the solid state can be carried on under ideal conditions, the resulting steel must be highly segregated. These ideal conditions would mean the long time subjection of the steel to a very high and uniform annealing temperature. Conditions necessary to ideal diffusion in the solid state are seldom approximated. Thus the only manner in which an unsegregated area of a steel casting can be brought about in commercial practice is by chilling and thereby undercooling during the period of change from the liquid to the solid state.

Guliver, in his paper "Departure from Equilibrium in Rapidly Cooled Solids," indicates that under a sufficiently rapid cooling rate there would be no diffusion at all, although he was not able to show a quantitative relation between the rate of cooling and the degree of diffusion. We feel that, in the making of a class of steel in which the presence of alloys in certain well defined quantities is necessary in the area near the surface of such castings, a method which will not permit the segregation of these alloys into the center of the casting is of utmost importance. This, then, is the first main reason for an accelerated cooling rate.

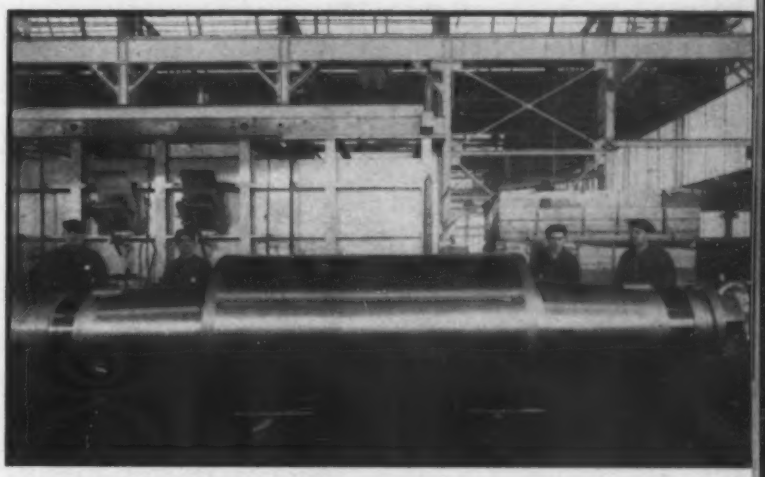
The second reason is the elimination of segregation areas in the surface area of the castings. All steel that is produced commercially, regardless of the degree of quality that is desired, will contain certain slag particles and various other non-metallic inclusions. In a steel casting which is permitted to cool through the solidification range in an ordinary manner, these inclusions will be found at random spots in the body of the casting and frequently will lie in an area somewhere near the surface.

In order to obtain a clear understanding of the rapidly cooled area referred to above, let us consider the effect of a chill upon molten metal. The chill, because of its low temperature, can absorb heat either by conduction or radiation from any substance having a higher temperature. This means that, when a chill is placed near a large mass of molten metal, heat is quickly extracted from that mass by the chill, and in the part of the metal which thus gives up heat certain alloys having high freezing points quickly solidify with the first drop in temperature of the molten mass, and these solid particles offer nuclei about which crystals readily form. Using the chill crystals for their base or nucleus, a somewhat different and larger type of dendritic crystallization then begins to form, or rather grow inwardly into the mother liquid. The growth and orientation of these exceedingly long dendrites must needs be unidirectional. True, crystal growth, if unimpeded, is invariably uniform in four directions. In this instance

Figure 4 — Roll molds being placed in drying ovens.

▲

Figure 5 — Large steel back-up roll after final machining operation.



the walls of the mold prevent growth outwardly; the growing arms or secondary axis of adjacent crystals soon meet one another and arrest all growth in any of the directions parallel to the walls of the mold, and the only direction remaining for uninterrupted growth is perpendicularly inward, where the metal is still too hot to allow the formation of fresh nuclei. Columnar crystals may or may not fill up the whole of the ingot; generally in large masses the center is cooled to the freezing point before the columnar crystals have grown across the ingot. If that be the case, the remaining metal then solidifies from any independent centers, the result being a center made up of fairly fine equiaxed crystals arranged in no particular geometric pattern ("Application of Controlled Directional Solidification to Large Steel Castings" by J. A. Duma and S. W. Brinson).

As soon as sufficient heat is removed from the molten metal, dendritic crystals will start to form along the inner boundary of the chill layer. These crystals will necessarily be elongated, as they must grow in the direction of the temperature gradient. There is little agreement as to the factors which determine the thickness of this zone. However, it is generally felt that these crystals cease to form at the time the effect of the mold is so decreased that slow cooling results. We also believe

that these crystals, as they form in toward the center of the casting, consist of a fairly constant and homogeneous analysis, and as they form they tend to push all segregates ahead of them into the center of the casting. According to the report on "Heterogeneity of Steel Ingots," "Columnar, like all growing crystals, have the power of rejecting out of their lattice more or less completely all foreign bodies not giving a solid solution. On this account the growing columnar crystals will reject and push before them a certain layer of slag. This will contain silica and sulphide grains assumed to pre-exist in the liquid, as well as sulphide successively thrown out of the solution on the solidification of iron."

And so it is that we believe that accelerated cooling can be expected to give us these two very necessary features in a steel casting wherein surface perfection is paramount: A dense homogeneous nature, and freedom from segregation areas.

Up to this point, we have dealt in generalities as applied to the solidification process of any type of steel. There are probably as many different classes of steel as there are uses for steel products; consequently, it is time for us to narrow down our discussion to that type of steel best suited for roll manufacture.

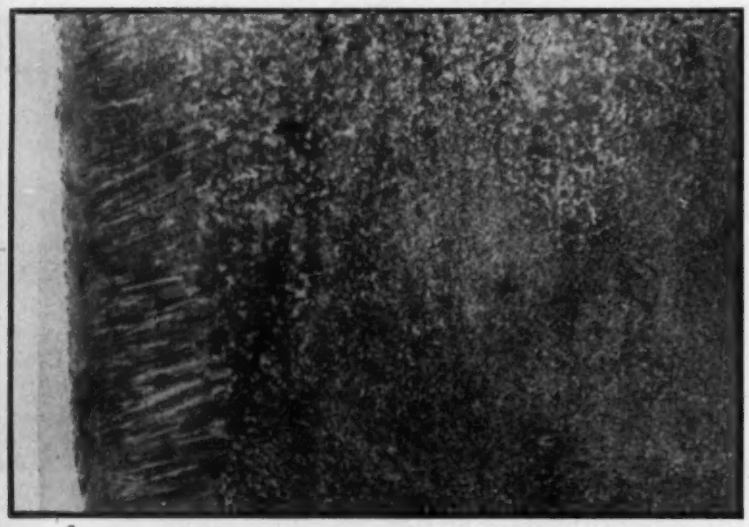
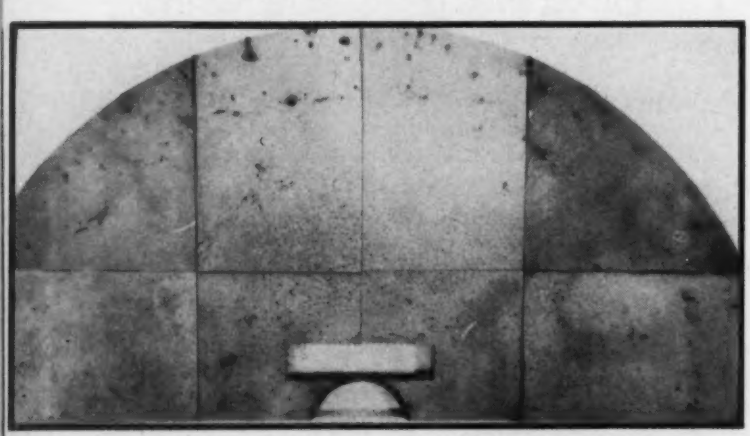


Figure 6 — Etched section of steel casting showing different structures in same casting caused by varied rates of cooling in that casting. This view shows a fine crystalline area at outer edge, an area of elongated crystals in the next portion and a group of equiaxial crystals in the center section.

Figure 7 — Slab taken from body portion of a casting 30 in. in diameter which was cast without using chills of any kind. Etching reveals segregation spots lying in area which would constitute rolling surface. When a roll such as this is placed in a mill, spalling is likely to occur very early in the service life of the roll.



There has been little research conducted along scientific lines to show exactly what type of crystalline structure makes the best roll metal. There are practically no tests that can be applied to rolls during their production. This entire industry has reached its present state almost entirely through a trial and error process. Little work of an experimental nature can be done when castings of the volumes which rolls attain are involved. It might be stated that our progress in roll production has been due more to statistical efforts rather than to metallurgical studies. True, considerable work is done in an attempt to determine just what grain structures are the most suitable, but so many variables enter into this study; and too, not all roll producers are equipped to carry such studies to definite conclusions, so the old process of putting them in the mill and seeing how they work out probably will continue to be the best method for testing. Of course, hardness is always watched very closely.

In a roll casting the most desirable features are strength, resistance to stresses in the mill, resistance to wear, and resistance to fire cracking. These are, of course, only the general qualities which are expected in all roll castings. In addition to these, it seems that almost every mill, and also almost every type of rolled product, demands some additional quality from the rolls which the roll maker must attempt to build into his product. Different mills work at different temperatures and at different speeds and with different designs of passes and on different materials, so that almost every type of roll produced needs some special attention if it is to stand up under the conditions which will surround it in service. To take a concrete example, often we will receive notice that a certain roll is fire cracking in service, and we attempt to change our analysis to meet this condition. Or again, we may learn that, due to peculiar driving conditions in a mill, certain rolls are not able to stand up in their present form and again we may strive for greater strength with a changed analysis. Frequently slight changes which may involve only very few points in some alloy constituents will serve to alleviate the troublesome condition, and it is in this regard that we feel that the greater degree of homogeneity that we can attain in the surface area of a roll casting, the better we will be able to control our decisions as to the changes necessary to meet specific conditions. Suppose that, on a roll which we learn from the mill operators is subject to excessive fire cracking, we decide to increase our nickel content in the analysis some thirty points when the replace roll is to be made. Now suppose that this roll is made under ordinary conditions which permit cooling through the solidification range at a slow rate, which is attended by the segregation of a considerable portion of our nickel addition into streak areas as the roll casting sets up. We are thereby losing in a rather large degree the effect of a change in analysis which might otherwise have cleared up the condition which had been encountered in roll service.

Up to now, we have touched but lightly upon that subject which has probably caused roll makers more troubles than any other single item, namely, segregation areas. By segregation areas we of course mean those

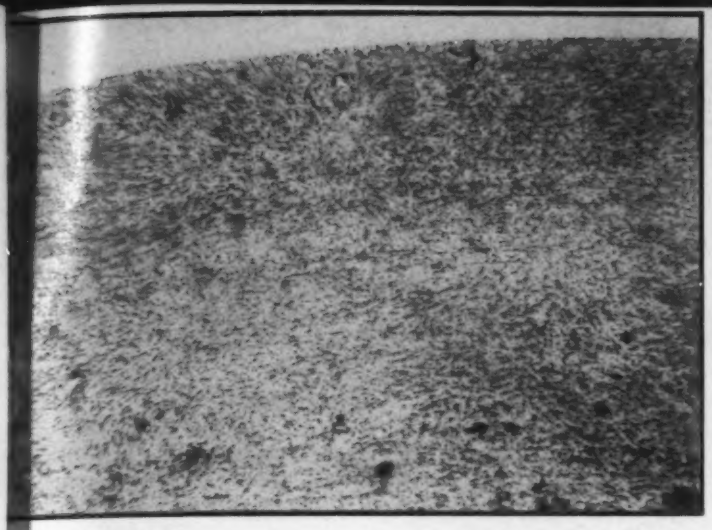


Figure 8 — Sulphur print taken by placing sensitized paper in contact with surface of roll at body shoulders. Segregated areas are revealed as dark spots. Above print shows one streak area to be less than 3 in. below roll surface. More drastic chilling could have "driven" this area further into the interior of the roll.

Figure 9 — Sulphur print which reveals no segregated areas within 5 in. of roll surface. Rolls from which such prints are obtained are properly chilled and experience shows that the best possible mill service will be given by such rolls. Outside diameter of roll is at top of picture.

areas or spots in which considerable portions of solids accumulate having a constitution which is entirely different from the surrounding portions of the roll casting. We do not mean to consider in this relation the phenomenon known as dendritic segregation, that slight trace of unwanted materials which forms along the crystalline boundaries and is found in all metals not of an entirely pure nature, but rather those accumulated areas which may be found in any portion of a steel casting. When such accumulations of segregates lie near a roll surface, trouble is bound to occur when the roll is put into use. It is not our intention at this time to go into a detailed explanation of our ideas with regard to the nature of these segregated areas (Figure 7).

Our roll inspection procedure provides that sulphur prints shall be taken on the body shoulders of rolls before shipment to reveal the presence of any segregation or "streak" areas, should they exist, and also to form a permanent and authoritative record of the actual condition of the roll before shipment. Figures 8 and 9 are taken from roll records. When sulphur prints show "streak" areas to be so close to the surface that roll service might be impaired, rolls are scrapped before machine work is completed. Again there is not too much agreement as to exactly what does cause these areas; some hold they are due to the presence of gas in the molten metal; sometimes it is believed that these areas form about a nucleus presented by some non-metallic inclusion, and that they draw out of solution certain elements for which they have a natural affinity, and that streaks in rolls arise from the tendency of such materials to flow upwards in the molten metal due to their lesser weight. When this occurs their presence is denoted by lines of softness which run the full length of the roll casting, increasing in intensity as they approach the upper part of the rolls and being especially evident on the cope shoulder. At other times it is believed that these segregated materials shrink downward in the mold as they become solid, and consequently lines of porosity follow in their path. Regardless of the source or the form which these segregates may assume — and we can say in all honesty that such segregates are present in every large roll casting — they need not be of any detriment to a roll if their location in the interior of that roll can be so controlled that they will never approach a wearing surface.

As pointed out earlier, rapidly forming crystals tend to push such segregates on into the center of the casting. We are quite certain that, if these segregated areas are held several inches below the smallest working diameter of the roll, no harmful effects due to their presence will ever be felt.

In the foregoing we have brought out what we think to be the most important benefits to be derived from a process of rapidly cooling steel castings, namely a denser structure and a steel that is more homogeneous in chemical analysis. There now remains another consideration in the study of rapid cooling of cast steels and that is the effect of cooling after the solidus point has been reached and on down through the critical range of the steel. It is during this period that the process known as granulation occurs. We have shown that steel, while cooling from the liquid to the thermal critical range, becomes solid through the formation of many dendrite crystals. However, the study of most cast steels reveals a very fine granular structure which would not be expected from the method of solidification which we have described. Micro-study of a cast steel specimen shows a fine crystalline arrangement of crystals, these crystals being so small they are usually referred to as grains rather than crystals.

Apparently, when steel cools below the solidification point, the dendrites undergo a process of granulation, and it is during this process that the dendritic nature of the crystals is lost. Based on observations of specimens taken from castings of large volumes, we believe that the more rapid the cooling rate during the solidification period, the finer this grain structure will appear to be after the casting has attained room temperature.

Summing up the qualities which can be expected from a rapid cooling process, we have:

Figure 10 — Solid metal chill.

1. Dense dendritic crystals of small size produced during solidification.
2. Homogeneous crystals produced by arresting of diffusion process during solidification.
3. Responsiveness to heat treatment.

RAPID COOLING IN ROLL MAKING

In beginning the roll making part of this discussion, let us first mention those elements which are accepted as being necessary to the manufacture of a first class product.

Rolls must first of all be made in an analysis which is suited to the conditions under which they will work; they must be made of a class of steel which is fully worked in the furnace so that a fully deoxidized steel results; and finally they must be cast in a mold the design of which will not permit the presence of cavities or voids in the roll body. The application of a method for accelerated cooling to the roll casting process is in addition to these essential elements.

Practically all steel rolls are made in molds comprised of sand tamped in a steel flask. Only the very small sizes are poured in a plain sand mold, however, as it is believed that directional solidification and control of shrinkage areas make necessary the use of some substances having a greater chilling capacity than sand. It is in this principle of chilling that our method of roll making is so widely different from the practice followed by any other manufacturer. In ordinary practice these chilling rings, made either of cast iron or steel carefully prepared to correct size and contour, are set in the roll flask in close proximity to the mold surface. On some types of rolls, they extend beyond the mold surface and in themselves constitute a surface against which the molten metal will lie.

As originally used, these chills performed but one function, the rapid cooling of the metal lying in contact with them with the object of cooling part of the casting to solidification, often while pouring is still in progress, so that in an isolated heavy section shrinkage cavities might be avoided. Thus the heavy section which is chilled might be fed from a thinner section which remains liquid longer than the chilled section and controlled solidification is thus attained. A second effect of this partial chilling is that the rate of cooling of a casting with light and heavy sections adjacent to each other is evened up, and the tendency for the sections to pull apart upon solidification is decreased.

These chills, whether they be specially designed chills to fit into the pass area of a swept out pass roll or whether they be plain chills used along the entire length of a plain body roll, can only absorb heat up to that point at which the temperature in the chill ring itself equals that of the section of the casting with which it lies in close proximity. After this point, the chill and casting will cool together in a slow manner. We do not think that the effect of any cast chill rings used in this connection can affect materially more than 20 per cent of the cross section of any roll casting, and because estimating of the correct thickness of chill to be used is made difficult by the presence of so many variables, we doubt very much that the effectiveness very often approaches such a high percentage.

Another method to produce an accelerated cooling rate for roll castings embodies a solid metal mold for chilling the body portion of the roll casting (Figure 10). This method is seldom used except in the production of plain body rolls. It is rather widely used in the production of backup rolls and its use is general in the iron roll industry. This method, too, results in an initial absorption of heat by the metal mold at a very rapid rate, which extends the rapidly cooled zone. However, in an attempt to obtain directional solidification, it is sometimes found necessary to taper the sand lining in these chill molds to such an extent that the chilling action of the mold near the cope end of the casting is practically non-existant. Even in those cases where the thickness of sand is held to one inch or less, the initial effect of the cast chill will cause the immediate surface area of the roll to become solid and to have a chilled structure. However, as the chill absorbs the heat of the casting, it soon loses its effect as a heat removing agent and the chilled area of the metal tends to again approximate the temperature that of the still molten interior, so that the area of a roll casting having a columnar crystalline structure is limited to that area immediately adjacent to the surface of the roll. To make this point clear, let us for a moment consider the action of a piece of steel which is heated to a high temperature for quenching in water. Immediately after quenching the surface of the steel is black, but within a short space of time after the piece is removed from the water, the heat of the interior of the steel restores the red surface of the quenched piece. So it is with a roll which is chilled with metal chills. After the chills have attained a high temperature by absorption from the roll casting, they lose their heat removing effect and the casting solidifies

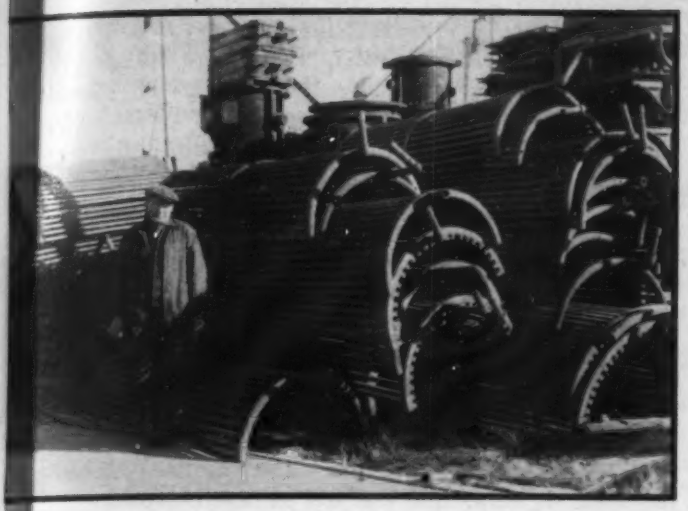


Figure 11 — Water chills for rolls. A large number of water chills must be available to carry on the production of the many different roll diameters.

Figure 12 — Setting cast chills (for pass roll) in place on water chill. All chills must be set to definite standard.

according to the natural laws of cooling with its attendant selective freezing.

In a plain sand mold, since the chilling action is relatively slight, it can be expected that the primary crystals are not very long and in all likelihood the greater part of the roll having this structure will be removed during machining operations. In a roll made with either cast chill rings or in an entire metallic mold, these primary crystals will be somewhat longer than in the case of rolls made in simple sand molds, but because of the limitations on this type of chilling the primary crystalline structure cannot extend to any substantial portion of the cross section of the roll. In a roll 30 in. in diameter, which is cast at approximately 31 in. to allow some stock for finish, the depth of the primary crystalline structure is probably not more than 2 or 3 in. on a side. Thus, when the outer half-inch of stock on each side is removed during machining, it can be seen that there will be only 1½-2½ in. of chilled metal forming a rim around the roll casting. Below this rim, the metal is usually of such character that the roll may be unsuitable for mill use when it is dressed down to these diameters.

Obviously then, the best method for chilling roll castings would be a method which would cause elongated crystals in the rapidly cooled zone to extend as far as possible into the center of the casting. In order to do this it was necessary that a means be devised to amplify the capacity for the chilling substance to absorb heat from the molten metal. Hence, certain foundry men experimented with the idea of spraying water on the outside mold surface. By removing the heat from the mold in this manner, the capacity of the mold to absorb heat was increased with a resulting increase in the chilling action upon the molten metal. Out of this practice, which in its original form was unsuitable to very close control, developed the idea for using water chills for increasing the cooling rate for castings.

During the last 40 years much was written concerning this method for chilling and it was widely used in various experiments with cast steels. However, most accounts of these experiments usually end with the assertion that the use of some type of circulating fluid is the best method for obtaining a drastic chilling action, whether this fluid be circulated through a series of pipes or in connection with a water jacket mold.

Our practice entails the use of a water chill which is made of steel pipe arranged in semi-cylindrical form (Figure 11). These chills are fabricated in half-sections so that they may be set in the two halves comprising the standard steel roll flask. Molding practice provides that these chills, when used, be covered with a layer of sand the thickness of which depends upon the amount of chilling desired for the roll casting and upon the chemical analysis of that casting. As is well known in the casting industry, metals of high nickel and chrome content cannot be subjected to as drastic chilling action as some of the plain carbon steels. In addition to this

Figure 13 — Cast and water chills in place in roll flask.

Figure 14 — Section of roll which ran out during pouring
This casting wall as shown in foreground was formed in 1½ minutes and is about ⅝ in. in thickness.

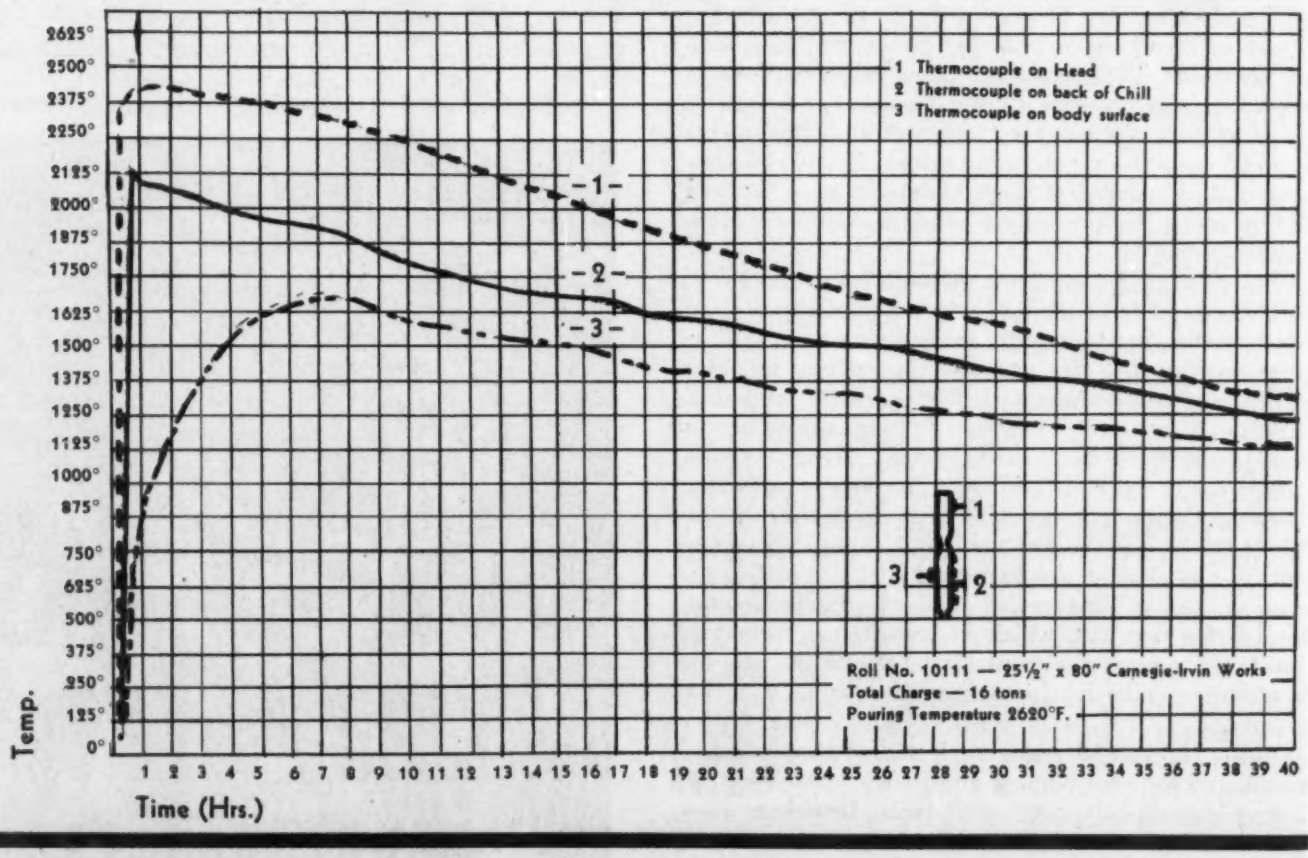
water chill, cast metal rings are used to conduct the heat from certain inaccessible areas of the roll casting to the water chill (Figures 12 and 13).

For the molding of plain body rolls, the water chill is used alone to chill the wearing surface of the roll, cast chills being placed in the mold adjacent to the roll shoulder to alleviate the stresses which would otherwise occur in those areas if the drastic chilling on the body of the rolls should be abruptly terminated at the start of the next section. For pass rolls, the same water chill arrangement is used but with the cast steel rings placed in direct contact with the water chill so that the heat abstracted from the molten casting is transferred through the cast steel ring to the water which is kept circulating under pressure of approximately 75 psi in the water chill piping. The constant flow of water means that the heat is continually abstracted from the cast steel rings and the effect of this chilling goes on until the entire roll casting has become solid.

In an effort to determine quantitatively the effect produced with the various types of chills which we have mentioned, a series of studies were conducted in the following manner: Thermocouples were placed at various points in the different types of roll molds in order to acquire the actual temperature conditions at such points during the solidification period of the roll. In the case of a roll made with cast chills along the body surface, one thermocouple was placed in contact with the casting surface at the center of the body of the roll, another in contact with the back face of the cast chill, and a third on the casting surface of the head portion of the roll so as to obtain a comparative reading for an unchilled section of the same roll casting (Figure 15). These thermocouples were connected to automatic recording instruments so that the actual thermal changes during the solidification period might be obtained.

For a roll made with cast chills we now feel that the following results are typical. Soon after pouring, the temperature of the thermocouple located on the head portion of the roll rises very sharply until it approximates the pouring temperature of the heat. From this high temperature a gradual straight line decrease in temperature can be expected. This decrease in temperature is brought about very slowly, so that for a 35 in. diameter roll there is probably a six hour period

Figure 15 — Chart showing temperatures recorded for roll molded with cast chills along body.



before a solidifying temperature is recorded. The time required for the temperature at this point to decrease of course depends upon the volume of metal in the roll casting. However, the interesting point to observe in this respect is that the metal does decrease in temperature in a gradual manner as shown in the graph.

In the case of the thermocouple attached to the back face of the cast chills (these chills were approximately 3 in. in thickness and were placed in the roll mold approximately ½ in. away from the surface of the roll), a rapid rise in temperature is again recorded, followed by a straight line decrease which is very similar to the decrease in the head portion of the roll casting, although the temperature readings taken from this second thermocouple are considerably lower than those recorded from the couple on the head portion of the roll. This indicates that the rapid absorption of heat by the cast chills is confined to a very short period of time, and that after the first two hours their effect rapidly diminishes. The rate of temperature decrease as recorded by the third thermocouple placed at the casting surface approximates that of the other two points, although its entire record shows a much lower temperature as a result of the initial absorption of heat by the cast chills. But again this also shows that these chills have little effect upon the rate of cooling after the first period in which the roll is becoming solid.

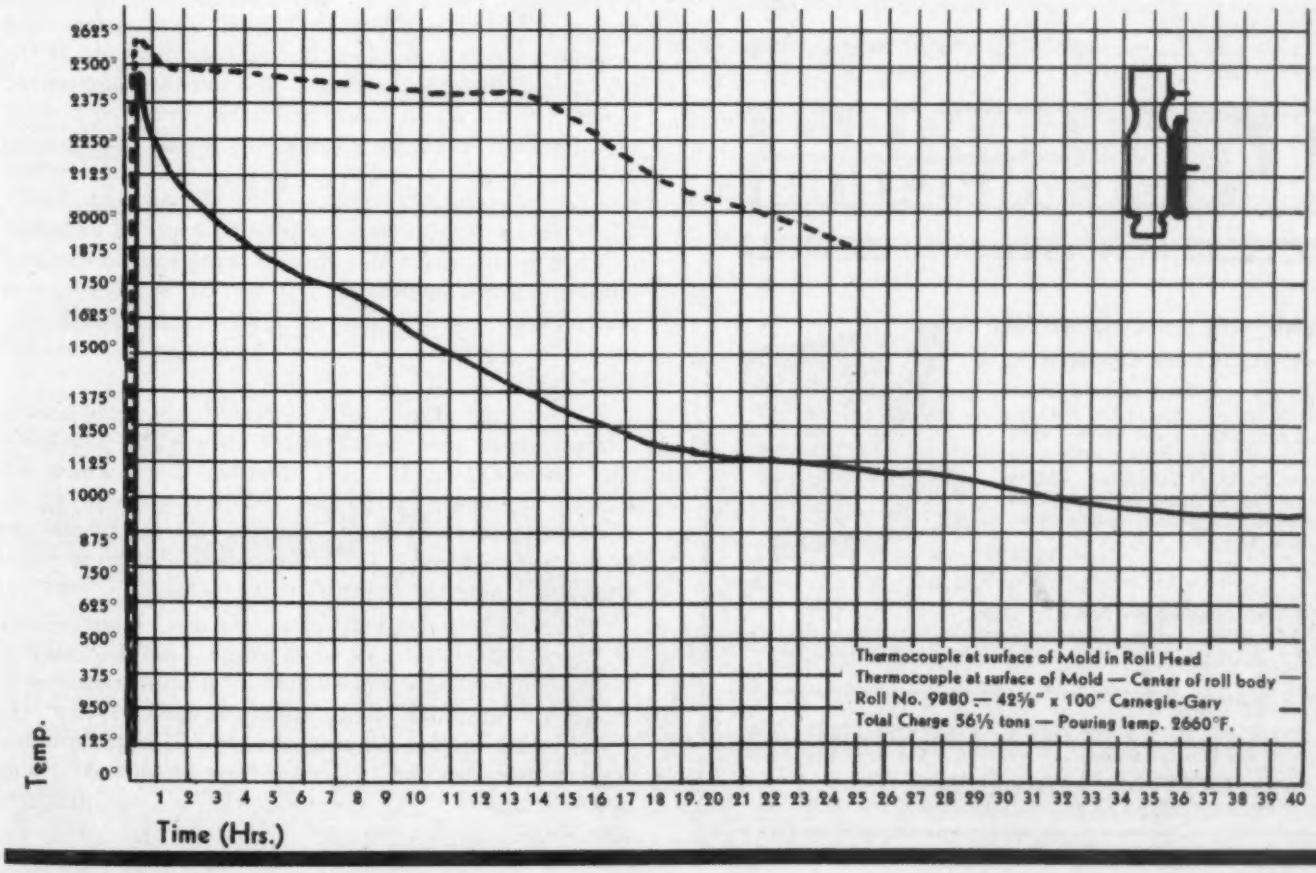
Now let us look at the manner in which a water-cooled roll solidifies (Figure 16). Our studies show that the initial effect on a roll cast in a sand mold containing a water chill is the same as that obtained from a sand mold either with or without cast chills, in that a chilled outer portion of the casting is set up immediately. From this point on, however, the reactions noted in a water cooled mold are entirely different. In our studies of water cooled molds, cast chills were placed at the mold surface on the chilled body portion. Since we can observe the temperature of the water at the outlet end of the chills, no thermocouple was placed on the back face of the water chills. The temperature of the water which circulates through the water chill pipes rarely exceeds a final temperature of 140 F, and in most cases the temperature is considerably less than this figure. Since the water at the inlet end ordinarily is somewhere below 90 F, the heat removing capacity of this method becomes quite clear.

On rolls made with water chills, the temperature of the head metal again approximates the pouring temperature of the heat following which a gradual decrease in temperature takes place. However, on the chilled portion of the roll, there is a very rapid decrease in temperature, indicating a rapid absorption of heat by the water chills.

We believe that it is during the period in which the sharp decrease in temperature for the roll surface is indicated that accumulations of segregates are pushed away from the roll surface area and on into the interior of the casting, and we believe that this action makes possible the production of rolls with surface areas free from streaks.

After observing all types of crystalline structures in steel rolls, we feel that the following general assertion can be made: Cast steels which are externally chilled exhibit a finer crystalline structure throughout the entire mass of the casting, and while the effect diminishes in the central portions of the casting, nevertheless

Figure 16 — Chart showing temperatures with water chill along body.



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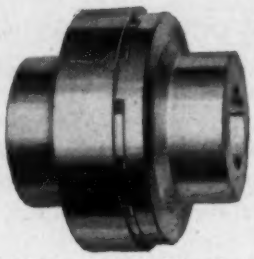

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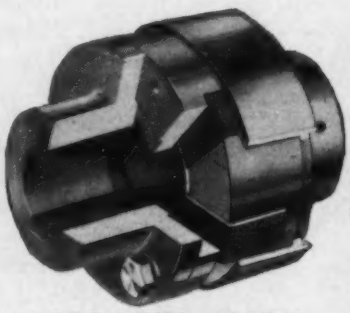

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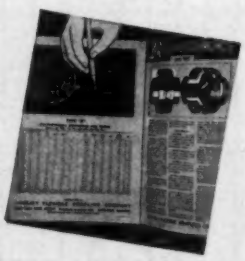

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even the very center is different in structure than it would be if no chills at all were used. Following this line of reasoning it can also be stated that the degree of refinement in the crystalline structure depends upon the heat removing capacity of the chilling medium used.

Now let us consider just what this finer crystalline structure means in terms of roll life. Since the main quality desired from a roll is resistance to wear without danger from breaking, the roll maker is forever confronted with a paradox. He must aim for that degree of ductility which will be sufficient to absorb various stresses and shocks encountered in mill usage, and at the same time, sufficient hardness to stand up under mill wear. The finer crystalline structures attained with chilled steels are held to possess greater ductility than steels allowed to cool slower, as well as lending itself better to deep hardenability. There are many references in the literature to substantiate this statement, of which the following excerpts from a paper by George A. Timmons, "Factors Effecting the Ductility of Cast Steel," is especially worthy of note in this connection:

"The solidification pattern and the degree of segregation of alloying elements which are dependent upon the rate of solidification have been found to exert an important influence upon the ductility of a steel casting at a given hardness, chiefly through their effects upon hardenability and the distribution of microconstituents. When a steel is highly segregated, its hardenability is lower than for the average composition and a faster rate of quench will be required to produce full hardening. If the critical quenching rate is not exceeded upon cooling from the austenitic state, regions rich in alloy content will generally transform at temperatures lower than those at which transformation will take place in the regions less rich in alloying elements. The resulting structure will, therefore, consist of two or more microconstituents varying in their mechanical properties and distributed in a pattern which resulted from the "coring" which took place during solidification. If the harder structure is distributed in a network pattern, or in any manner which definitely breaks up the continuity of the softer, more ductile matrix, plastic deformation in the latter will be restricted and the resistance to flow will be appreciably increased with respect to fracture. The steel in this condition will be susceptible to failure in a brittle manner with a low absorption of energy and will, therefore, be less fit for service applications in which high concentrations of 3-dimensional stress may prevail or where the rate of load application is moderately high.

When a cast alloy steel which is highly segregated is normalized or annealed, there is always the possibility that there will result a soft, ductile, matrix which will contain wihin it a harder network that will restrict the plastic deformation of the matrix, thereby raising the flow stress with respect to the resistance to fracture and thus decreasing the ductility of the steel.

The columnar dendritic structure often found at the surfaces of steel castings, when sound, has been found to possess higher hardenability than the interior, "equiaxed," or "granular" structure of the same casting. The distribution of the alloying elements is more uniform and the solidification pattern is finer. Such a structure, when properly heat treated, will possess excellent ductility . . . . "

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THE WIRE WITH PERMANENT INSULATION

• BUY MORE WAR BONDS •

Developments IN THE IRON AND STEEL INDUSTRY DURING *1944*

W. H. BURR

ELECTRICAL SUPERINTENDENT
LUKENS STEEL COMPANY
COATESVILLE, PENNSYSVANIA

. . . . this material was prepared by the A. I. S. E. Development Committee, of which Mr. Burr is chairman . . . .

▲ UNQUESTIONABLY the most difficult problem facing the steel industry during 1944 was the manpower situation. Not only was it the prime factor in limiting tonnage output, but it also dictated to a considerable degree the type of products to be turned out. Through a welter of claims and counter claims, one thing stands clear — a sound manpower policy, set up and adhered to by properly administered agencies, would have resulted in a greater steel tonnage.

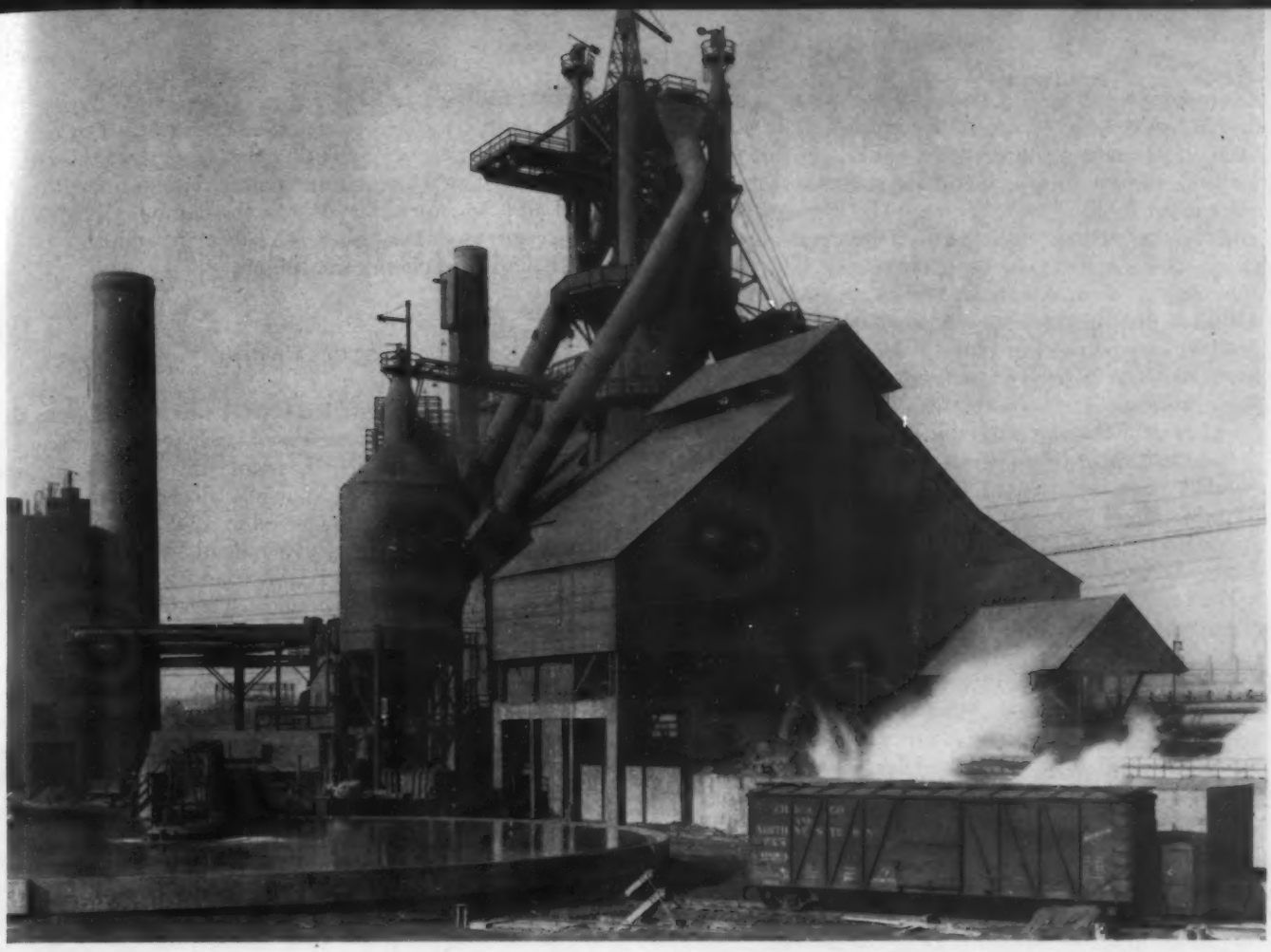
The same shortages which were apparent in 1943 existed last year although in some cases the emphasis was changed slightly. The most difficult problem continued to be the supply of plates, but beginning in the late second quarter and gaining steadily was the demand for large rounds engendered by the heavy shell program.

Despite manpower shortages, labor troubles, transportation difficulties and material shortages, the expanded industry was able to turn out 89,500,000 tons of ingots in 1944. This is only a slight gain over the preceding year, but it was accomplished with several thousand fewer workers and represents what might be considered an almost impossible accomplishment.

There was relatively little new capacity brought into operation during the year, in comparison to the two preceding years. Considerable additional plate capacity, and semifinished capacity to feed it, was started in operation, but on the whole, the problem was one of refinement and boosted efficiency on the part of existing equipment.

There is no doubt that during the entire year the accent was on production. Although the industry has had an eye to the future, and there has been considerable work done on evaluating the postwar situation of the industry with regard to increased capacity, possible markets, manpower requirements and other problems, the big job has been to turn out the steel. For a period in August and September, it appeared likely that the postwar problems were going to be laid on the line very suddenly, and there were some feverish preparations, notably paring of inventories and a resulting break in scrap markets; a wave of inquiries for civilian steel tonnage, which most producers wisely shunted to one side; and the start of cancellation on many limitation orders from governmental circles. However, this situation cleared up when the going got tough on the road to Berlin, and by the close of the year it became apparent that there would still be many months of pressure on production facilities without the aid of much civilian tonnage.

It does seem probable, however, that the makeshifts of the industry will be cleared out in the near future. Already the new plate mills, plus a drop in the overall plate requirements, have set the stage for a housecleaning of the temporary cooling beds and shear lines



One of the new government-owned blast furnaces which has contributed to overcoming the pig iron shortage in the United States. These units are for the greater part capable of independent operation, although located in conjunction with existing privately owned plants.

which have sprung up around some of the strip mills. The rail program is clamoring for more space and will probably shove some of the billets off the rail mills and out of the export markets.

The little relief from production pressure granted by these and other similar moves has already resulted in a little more thinking and some action, both intra- and inter-companywise, about the new technical developments which have been under wraps for the duration because they deal with civilian goods to a large degree. One example of this has been the new developments in tempering sheet and tin mill products. Another is the new developments in mill-applied finishes, including some of the electroplated metals. The question of hardenability and its effect both on steel producing and steel buying is getting much wider attention, and so, too, are a number of other problems from the ore mine to the packing extras.

BLAST FURNACES

Despite the fact that capacity increased over 1943 levels, total iron production was only a million tons higher, at 62,000,000 tons for the year. The real answer to this situation, which produced a 90 per cent operating rate for the year against nearly 98 per cent in 1943, was lack of demand.

The manpower problem was serious at some points, but more iron could have been made had there been a market for it. By the third quarter, there were a dozen idle stacks with no orders, and by the close of the year there were several more added. Admittedly some of these stacks were high cost producers which were unable to find any customers at high price levels, but the fact remains that our capacity to produce iron is once again above our capacity to consume it.

Some of the new stacks which were scheduled to be in operation in 1944 have not yet been completed; work has been halted because there is no need for their products. Undoubtedly these stacks will be completed after the war and put into operation to replace less efficient units which are now operating.

In contrast to 1943, when there was considerable fear that the ore shipped down the lakes would not be adequate and the season was prolonged beyond its normal close, the 1944 ore shipments were in excess of needs and the season closed early. Total shipments were 80,200,000 tons, adequate for the industry's needs, and well within the estimated 110,000,000 ton ore carrying capacity of the present augmented fleet.

Despite the ample supply of iron ore at present, there has been continual research on beneficiation to make use of lower grade ores. During the past year, additional reports have been made available on nodulizing ore in the rotary kiln, a process which has been in

intermittent favor and disfavor for many years. At first introduced as a means of bypassing the blast furnace, it is now recognized to have some merit as a method of producing metallics suitable for further refinement in the blast furnace. The Bureau of Mines program on sponge iron research was continued, with most of the activity focused on rotary kiln plants at Johnstown, Pennsylvania, and Laramie, Wyoming. Although the Bureau hopes to prove eventually that this product can be used in place of heavy melting steel in the open hearth or electric furnace, there as yet have been no positive results in this direction, at least insofar as cost of the raw material is concerned.

Likewise, operations were started on the direct reduction unit installed at the Warren, Ohio, plant of Republic Steel Corporation. It is understood that some operational difficulties have been encountered and no detailed report has been forthcoming as yet.

Washing and screening of iron ores, as well as fine grinding followed by sintering to obtain high iron concentration, are being studied closely by blast furnace operators. Wider use of such materials will undoubtedly force a change in blast furnace operation, and some experiments along these lines are now being conducted. Furnace production varies widely between a soft ore burden and a full sinter burden, and changes in practice must be established to take care of this variation.

Moisture control in the air supplied to blast furnaces seems to have proven itself definitely advantageous in increasing production and in holding consistent analyses. Active controversy still remains, however, between proponents of the very low moisture idea and those who favor close control of the moisture at higher levels.

Although European furnaces, notably German, have used carbon refractories for some time, it was only recently that the first American blast furnace was lined with carbon refractories, and it is expected that others are to follow. It is quite possible that this may prove to be the beginning of a trend toward more widespread use of carbon as a blast furnace lining. Carbon has a low coefficient of expansion and shows little shrinkage in use, which means that stresses caused by uneven heating zones would be minimized. There are fewer joints in the carbon lining because the size of the refractory is limited only by the furnace design.

Several new batteries of byproduct coke ovens were contracted for during the year, and some new batteries placed in operation. The new units contained several batteries which will replace older installations, indicating a continuation of the trend toward a greater yield of byproducts.

This expansion in byproduct capacity, which pushed the annual capacity of the country to 70,000,000 tons, with an additional capacity to come when new units are completed, probably rang the death knell for the 8,000,000 tons of beehive capacity, centered largely in Western Pennsylvania. Beehive operations through 1944 suffered from declining demand and a progressively tighter supply of adequate coking coal, and during the fourth quarter operated at below 70 per cent of capacity, still dropping.

Importance of coke oven byproducts in the postwar period has not been minimized, and additional facilities for producing more complex end products were completed and ordered for future completion during the year, both by steel operating companies and by public utility coke plants. Indicating the strength of this trend, one company changed its name to eliminate "iron" and add "chemical," although the company during the year operated two blast furnaces in addition to its coke plant and chemical adjuncts.

STEELMAKING

Most of the gain in 1944 steel production over the 1943 figure came from increased open hearth operations. The total of open hearth ingot output was slightly under 80,000,000 net tons, while electric furnace steel contributed about the same as in 1943 at a little over 4,000,000 tons, and bessemer output likewise remained static at 5,000,000 tons. Highest month in the year was March, with a weekly average of 1,765,000 tons of ingots from the three sources, a new all-time high.

The total capacity for open hearth steel production is now a little more than 82,000,000 tons. This figure, tremendous in comparison with prewar production levels, has caused some concern among steelmakers, particularly when it seemed probable that war steel demands would be drastically lowered after the fourth quarter. It is generally conceded, however, that when the pressure for production is off, many currently operating open hearths which have outlived their economic usefulness in a free market will be scrapped in favor of more concentrated production in the newer, more efficient units. It is also true that some of the open hearth capacity is so located that its peacetime applicability will be limited to periods of extremely high demand, or will be dependent on establishment of new markets geographically favorable to these plants.

Open hearth melting stock changed in character somewhat during the year, with suitable scrap more plentiful. The iron-scrap ratio was changed at many plants during the year to reduce the quantity of hot metal in the charge, and at other points production of blown metal or "synthetic scrap" was reduced or eliminated.

On the technical side, new open hearth developments were few. The advances were largely in the field of closer control, with considerable work being done on the problem of bath temperature and controls on fuel and on refractory temperature.

Automatic temperature control on open hearth roofs is now accepted practice on many of the furnaces setting production records. Several hundred extra heats have been tapped from some of these furnaces with the roofs still in good condition. Radiation pyrometers are aimed at the roof, and when the preset temperature is reached, the heat is automatically cut off. Prevention of overheating is probably the most important factor in increasing the life of open hearth roofs, and this system has proved itself in a number of different installations.

On the maintenance side of the ledger, new wrinkles speeding up the maintenance processes and cutting down the number of man-hours required for the job provided most of the news. One piece of equipment announced last year which does both of these things is a steam operated vacuum conveyor unit, designed

primarily for cleaning checkerwork, flues, stoves, gas lines and the like. It has proved its effectiveness by showing a reduction of as much as 60 per cent in man-hours required for cleaning furnaces and by reducing the time required for furnace rebuilds, and a considerable number of installations have been made.

The electric furnace picture showed some new angles during the year as a result of declining demand. Lower demand resulted in some lower prices in alloy steel markets, and also caused a considerable amount of thought about the postwar prospects for these steels, and in particular, the outlook for stable prices and markets.

It is obvious, of course, that the basic electric furnace will be the primary production tool in high alloy, stainless and tool steels. There is not enough of this tonnage, however, to keep all the electric furnace capacity engaged. The obvious next step is to gather in some additional high quality steel tonnage now made in open hearths. This will require the reduction of the overall cost of electric furnace steel to an equal basis with the open hearth on the low alloys and high quality carbon steel forging grades.

One possible source of such economies lies in continued research on the chemistry of electric furnace steelmaking. Considerable work has been done on this subject, and researches are continuing. However, the gas-slag-metal reactions in the electric furnace are still virtually unknown in comparison to the data now available on the open hearth, and it is possible that a better understanding of the "how" of electric steelmaking may completely realign costs.

It has been found in some cases that the use of roof rings of a diameter larger than the furnace shell has given the skewback brick added protection by moving them farther from the heat sources, with the result that overall roof life is increased. Electrode cooling glands have also been modified to aid in increasing roof life. Water cooling has been extended in some cases to include the entire electrode arms, with the idea of extending their life. A pneumatically operated electrode clamp, in which a spring operated wedge holds the electrode securely in place and a pneumatic arrangement releases the spring wedge to permit slipping the electrodes when desired, is said to offer operating advantages.

Hydraulic operation of electrodes is available, and is said to give smooth, accurate operation, but has not been widely adopted. Rather, the trend has been toward the rotating type of electrical control. The recent introduction of electronic regulation for electrode control may stop this trend, as no moving or vibrating parts are involved and standard electronic tubes provide the dual function of control and rectification. This eliminates the necessity for providing d-c power for the electrode motors. The installation of furnace controls to limit current input to the value giving maximum power input should aid in increasing operating economy.

Especially designed for sidewalls, a new refractory mix has been developed which is applied by means of a gun and which can be applied at temperatures of 2200 F or below. It is a basic magnesia type refractory, and can be applied as soon as the bottom is made up in small furnaces. In larger units, some scrap is usually charged first. The gun weighs 150 pounds exclusive of the hose and requires about ten minutes to set up. The refractory has been used successfully in soaking pits and small open hearths.

The continuous casting will-o-the-wisp seemed to come a little closer this year as researches on the two most promising methods for steel reported varying degrees of success. In the Williams process, steel is cast at high lineal speeds by the use of a relatively shallow cooling passage surrounding the mold wall. Water or other cooling fluid is passed at high velocity along the outer surface of the mold wall, which effectively "scrubs" the heat away from the wall.

This fast removal of heat in turn lowers the temperature gradient through the mold wall and compels a faster flow of heat from the molten metal. The result is an increase in the speed of formation and the thickness of the ingot skin, enabling it to be drawn along the surface of the mold at higher speeds without rupture.

This battery of 250 ton tilting open hearth furnaces is installed in conjunction with electric arc furnaces for duplex operation. These units are in a DPC plant in the Chicago district.

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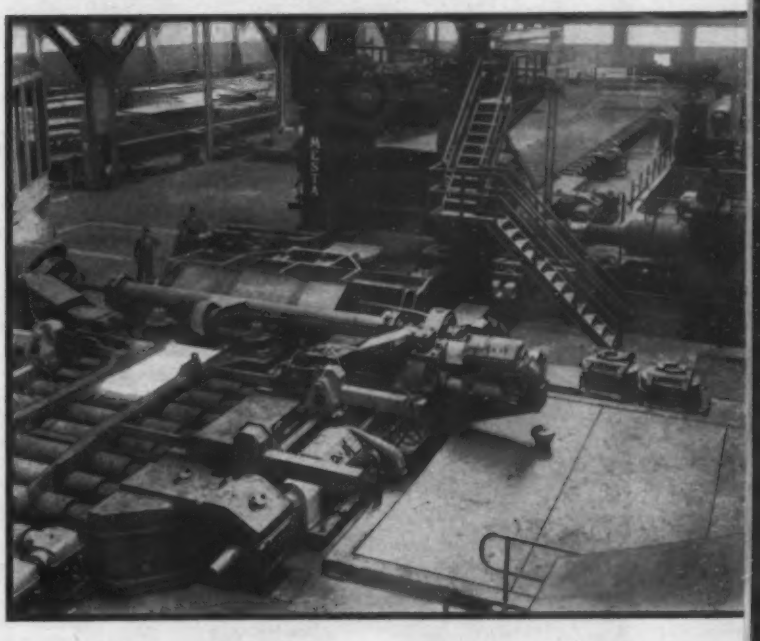
Plate mills again led other types of finishing mills in tonnage. Plate requirements are still close to capacity in spite of recent expansions.



This process has been built on full scale and has made some experimental heats, but there remains a number of technical difficulties which must be eliminated before the process can be termed fully commercial. Real progress has been made, however, and the possibility of ultimate success seems good.

The second process which appears to have possibilities is the Goss system, which has cast metal in a pilot plant but has yet to be demonstrated on full scale. The principles involved in this process are virtually the same as in the Williams process, except that a special "preforming" chamber is used ahead of the cooling mold, and lubrication is supplied inside the mold under pressure.

ROLLING MILLS

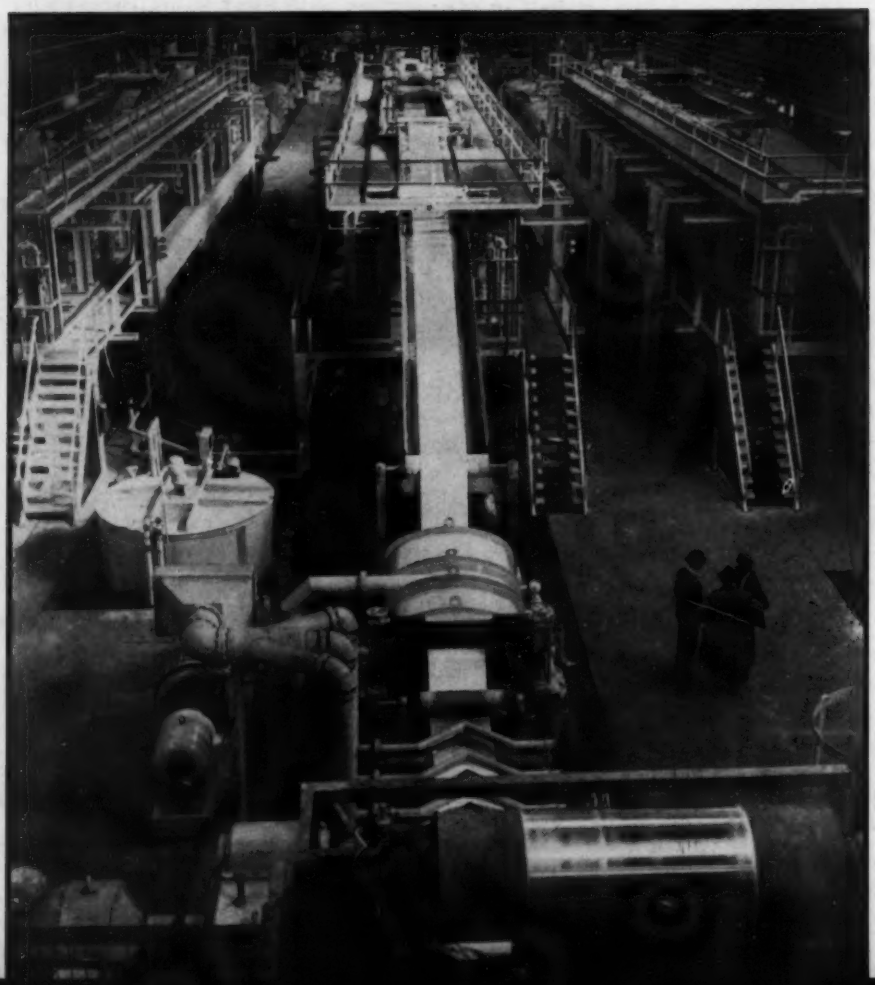
Rolling mill production patterns in 1944 followed closely on 1943 lines. Plates again led all production with slightly more than 13,000,000 net tons, closely followed by sheet products at about 12,000,000 net tons. Bar mills turned out an almost equal tonnage, and the tin mills showed a substantial gain over 1943, reflecting larger directives and greater production on the electrolytic lines.

New technological developments were relatively fewer during the year than in prewar years, as has been the case over the past two years. This was probably due to the fact that the heavy expansion program was largely completed in 1943, with the exception of some plate facilities and a sprinkling of other installations.

Although the industry in 1944 did not continue the tremendous expansion of the preceding years following Pearl Harbor, there was considerable activity aimed at increasing production. This was due primarily to an acute eye for detail in ironing out kinks in new equipment and refining older mills to produce still more steel. Higher speeds and closer control, with increased use of automatic controls keynoted many of the new developments. Cold strip mill speed has now reached 4100 fpm, and 6000 fpm is being seriously considered. Auxiliary exciter mill controls blossomed forth in numerous existing mills as well as new units.

Probably the outstanding single development in rolling mills during 1944 was the introduction of a new temper mill, a single stand unit based on the principle of stretching the strip uniformly while moving at high speeds. The design was placed in limited production in 1942 on an experimental basis and one unit was placed in full operation in a Youngstown district mill in 1944. In appearance, the unit resembles a conventional 4-high mill stand, but in reality consists of two 2-high units in one stand, one above the other. The strip enters the upper 2-high, circles the lower roll and passes between that roll and the upper roll of the bottom 2-high without pressure, and then leaves the mill through the bottom 2-high unit. Tension is exerted between the two units, and the method of rolling is said to impart superior temper to the strip while maintaining good ductility. A detailed article on this mill is published elsewhere in this issue.

A newly designed vertical precision mill has been developed which rolls accurate rounds from ⅜-inch to 1½ inches in diameter. A large percentage of the product can be rolled within cold drawn tolerances, and the mill can be set up so as to edge shapes and flats. Design of the mill is extremely rigid and simple. The mill stand consists of a pair of vertical rolls located immediately after the finishing stand of a conventional



Already the steel industry is experimenting with their electroplating lines with a view to determining their usefulness for coating strip with zinc and other metals.

mill. The precision stand can be moved horizontally to line up the pass line with any pass in the horizontal rolls of the finishing stand. The vertical rolls are 12 inches in diameter and 15 inches long, and are supported by antifriction roll neck bearings in a cast steel carrier. They are adjustable so as to control product size.

Although not yet applied to ferrous rolling, the commercial application of the Krause mill in rolling nonferrous metals is of some interest in that its inventor claims the possibility of steel rolling. Of unorthodox design, the mill works on a principle of slow forward motion and heavy reductions. Rolls of small diameter are held in alignment in a cage placed in a reciprocating housing. Draft of the pass is determined by wedge shaped cam plates inside of the roll housing which is reciprocated back and forth by a crank motion. The metal is pushed through the mill intermittently, being held stationary during that part of the housing stroke that the rolls act to squeeze an increment of strip length down to the desired gauge. This mill is currently in production on brass and copper strip, and has also been used experimentally on aluminum. Some very early work on an experimental mill showed some promise in the rolling of steel (Iron and Steel Engineer, August, 1938.)

Over the past few years, considerable progress has been made in developing better performance in cast steel rolls, due in part to a better understanding of the effects of alloys and of cooling rates. Recently the trend has been to use several alloys rather than a single alloy, and a large proportion of alloy rolls now contain nickel, chromium and molybdenum. Three widely used types are as follows:

	Blooming and slabbing mills	Back-up rolls	Shape rolls
Per cent C	.90-1.20	.65- .90	1.40-2.25
Per cent Mn	.....	.60-1.20	.60-1.00
Per cent Ni	1.00-2.00	1.50-3.25	.75-1.50
Per cent Cr	.35-1.00	.60-1.10	1.00-1.25
Per cent Mo	.20- .40	.25- .50	.20- .35

Each of these types offers a range sufficient to meet variations as dictated by roll size, hardness, etc., and heat treatment is also varied to give the desired characteristics.

At least four large strip mills are using a newly developed spherical roller bearing to absorb heavy thrust loads experienced with back-up rolls supported radially by oil-film bearings. The new bearing has high load capacity, rolling alignment, and the ability to run at sustained high speeds with low friction. The bearings are intended for use in all severe duty applications, such as the worm thrust in screwdowns, large speed reducer units, large high speed pumps and the like.

Laminated phenolic rings have been used in at least one recent installation on the end of the back-up rolls to seal the water out of the oil. Pressure against the end of the roll barrel at about 10 pounds per square inch was supplied by springs placed in counterbored holes. This effects a seal so that the water used in cooling does not enter the bearings.

An interesting recent development has been the heavy duty flame cutting unit designed to carry special torches which can cut ingots and slabs 18 to 50 inches in thickness, and in some cases even thicker, at speeds ranging from 1 to 44 inches per minute. The torches are water cooled and of a new design styled to carry extremely large volumes of gas per hour. Several billet cutting setups are in operation using this machine.

FINISHING

The most interesting developments in metal finishing during the past year came as byproducts of the electrolytic tinplate lines. Using a standard line and changing only the electrolyte, a high-speed tin line was slowed down to produce continuous zinc-coated strip in commercial quantities. On similar equipment experimental work in coating strip with other metals has been carried out. A new process has also been developed whereby steel strip is coated in coil form with a wide variety of plastics, lacquers and synthetic resins.

Accelerated by the demands of war production, new nickel electroplating processes have been developed which promise to receive wide application in postwar manufacturing to provide a protective and functional coating for iron and steel. Plating solutions, operating conditions and cycles have been modified so as to produce deposits with predetermined physical properties.

Indeed, electroplating equipment has been developed to point a where it is available in "packaged" form, completely automatic in operation. Such units are composed of mechanisms long in use in plating processes. The assembly into a complete automatic unit brings production line economies to the electroplating of a wide variety of parts which compose perhaps as much as 80 per cent of plating work.

Continued use of synthetic rubber has been successful in a number of applications in strip finishing equipment. In a bonderizing unit, synthetic rubber rollers functioned satisfactorily for 10 months (20,000 tons of production) without replacing. Synthetic rubber can be so compounded as to give the exact characteristics required by the application — resistance to oil, heat or chemicals, degree of hardness, etc. This "tailored-to-fit" property makes synthetic rubber rollers applicable for bonderizing units, tinning lines, strip picklers, scrubbers and galvanizing units.

Interest continues in semi-continuous picklers, several of which have been installed in plants of relatively small capacity. The term "semi-continuous" is used because each coil is pushed separately through the respective tanks in the line, eliminating the welder, stitcher, looping pits and shear, and materially lowering the installation cost of the unit. With proper handling facilities, pickling lines of this type can be operated by a crew consisting only of a foreman, two operators and a crane man. Maintenance costs are low because of the simplified design and methods of construction.

To protect wood, steel or masonry surfaces against the corrosive action of all commercial acids and alkalies, a flexible, impervious coating has been produced having a softening point of about 275 F. The material may be troweled on or, if diluted, it may be sprayed. It is useful as a protective coating for ducts, hoods, piers, structural work, etc. in pickling and cleaning departments, and may also be used to give an acid-proof, leak-proof membrane in brick-lined construction of tanks, sewers, pits, etc.

Because of the magnitude of the shell program, the heating problems involved in it have presented the industry with its biggest and in some ways its most complex furnace job. This program was well under way before 1944, but it was during the past year that the methods devised to heat and form bombs and shell were really proved under volume production. The continued heavy demand for these artillery items promises that the coming year will see an even further expansion of such facilities. In addition to uniform high speed heating, furnaces for shell heating have of necessity been simple in design and operation so that they could be handled by inexperienced help. This has required a larger degree of automatic control than ever before. The need for speed has resulted in considerable use of the induction method of heating for nosing operations in the production of shells. The amount of heat generated in the end of the shell can be graduated so as to obtain a smooth rate of curvature from the body of the shell to the end of the nose.

Induction heating is receiving broad application in heat treating, melting and forging operations. It has been found particularly advantageous in heating for shell nosing.

It seems probable that much of the research work on heat treatment, both in the actual heating and in cooling cycles, including quench methods, will result in a much wider use after the war of the lower alloys and carbon steel. Much better procedure has been developed to attain and hold better physicals in these relatively "lean" steels, minimizing the need for expensive alloys in many applications.

In connection with the development of rotary and continuous forging and heating furnaces on the shell and bomb lines, it has been due in a large part to long-lived refractories that these furnaces have set production records. Special refractories of the alumina-silica type, double calcined at temperatures several hundred degrees above the maximum operating temperatures, have given campaigns of as long as two years, as compaved with five to seven months for normal refractories. Insulating brick, particularly in the rotary furnace roofs, have added considerably to the length of service which can be obtained without relining.

Development of new types of porportioning control, and more widespread use of this development on heat treating furnaces of virtually all types, both batch and continuous, has led to a reduction in scaling from atmosphere contamination. Controls of this type usually provide flexibility in the supply of fuel, as opposed to the on-off or two position control, thus maintaining a constant pressure inside of the furnace at all times and preventing entrance of outside atmosphere.

Rapid continuous heating as an adjunct to the continuous production line comes a step nearer as a result of a newly developed furnace which concentrates high heat release in an unusually small heating zone. For example, on an early installation of this heating method, brass and copper rod is continuously annealed in a heating zone only four feet long at a speed of 23 feet per minute on ¼-inch stock, or two feet per minute for 1½ inch stock. Stainless steel tubing ¾-inch in diameter and with a wall thickness of $\frac{3}{32}$-inch is clean annealed at a rate of 13 feet per minute in a gas-fired furnace with a heating zone only 13 inches long. The heart of the new development is a special gas burner which permits combustion of large volumes of gas over relatively short periods of time in confined areas. Experimental work on steel in sizes up to 8 in. x 8 in. have shown extremely rapid heating rates without detriment to the material, and it is thought that the method will find a number of applications.

A new wrinkle in strip annealing involves the use of a special type of cover furnace with an added heating unit extending down from the center of the top. The furnace, cylindrical in shape, thus provides heat not only to the exterior surface of the coils but also to the interior diameter. Because the coils can be heated both from inside and outside, a more uniform heating as well as more rapid heating is achieved.

The use of controlled atmosphere furnaces has continued to spread in the past year. The technique of handling metal in a controlled atmosphere furnace is becoming more widely understood, and instead of the system whereby commercial heat treaters were called upon to do this type of work on contract, an increasing number of manufacturers have established their own departments, headed by trained technicians, to do almost any type of heat treating required. This has probably been spurred by increased knowledge of what a proper furnace atmosphere will accomplish. In a prepared furnace atmosphere, all types of alloy or straight carbon steels may be annealed on long cycles without either oxidation or decarburization. Many applications of prepared atmospheres use a commercial fuel gas burned under controlled conditions with subsequent thorough removal of carbon dioxide and water vapor. The resultant gas, inert and nonexplosive, contains a high percentage of pure dry nitrogen, with just enough combustible to react with impurities in the furnace.

The amounts of oxygen and combustible present in a gaseous atmosphere may be determined and recorded by an instrument which can also be used as a controller. To measure the oxygen content, an analyzer

unit mixes a sample of the gas with the vapor from a standardized liquid fuel. Catalytic combustion of the mixture on a metal filament burns the oxygen from the sample, and the heat developed by this combustion changes the electrical resistance of the filament, which is in turn measured in terms of excess air by an electronic type recorder. A second unit located in the same recorder measures the combustible content of the same gas by burning catalytically on a second metal filament the combustible. In this case, no fuel is added to the sample. Records of both the oxygen content and the combustible content may be made on the same chart. Other oxygen recorders based on different principles have also been developed over the past year or more.

Overcoming the difficulty often experienced in continuous furnaces from cold spots caused by the metal skid rails or pipes, the use of skid rails of silicon carbide is also said to improve furnace efficiency, and a number of installations have been made. These refractory rails replace either alloy rails or water cooled pipes. Advantages claimed include longer life, reduced maintenance, elimination of cold spots and lower installation cost.

As a means of reducing the time required for rebuilding furnaces, insulating refractories are now made in standard sizes up to 9 x 24 inches, more than five times as large as standard brick. The refractories are made from a high quality clay rendered porous by burning out an organic filler, as usual in material of this type. These products, manufactured in various grades for use at varying temperatures, can be used wherever the regular insulating firebrick is recommended. The large sizes assure fast, economical installation, with a minimum of joints. The material can be easily cut with a saw and shaped with a rasp, making easy the formation of special shapes.

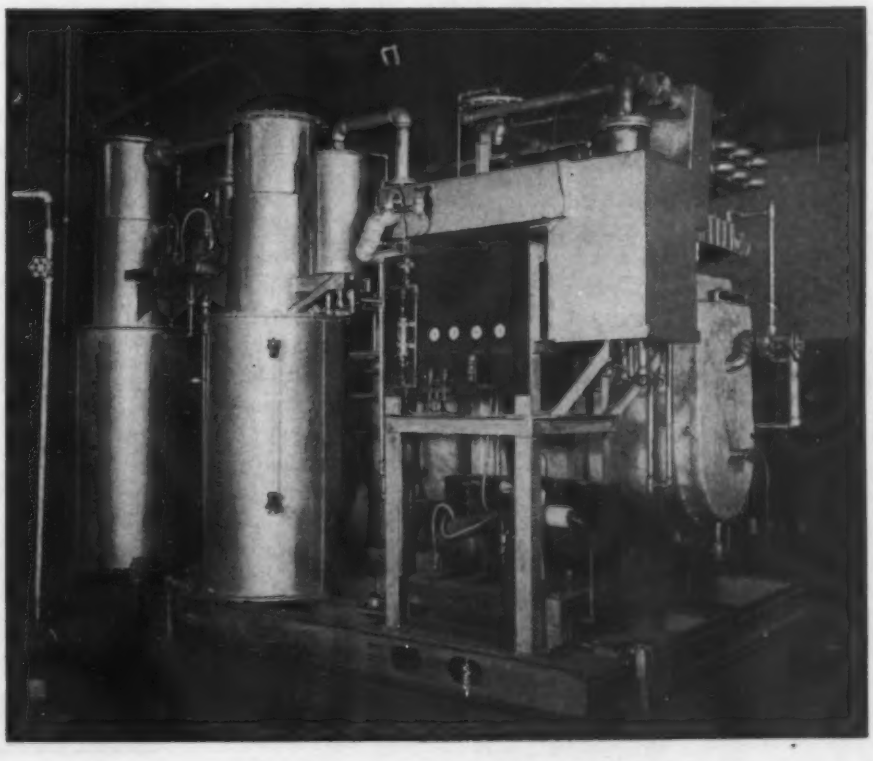
MATERIALS HANDLING

Returning to the shell program mentioned previously in this report, it should be noted that a large percentage of the demand has been for 8-inch and 240 mm. shells, either of which is too heavy for an able bodied workman to handle constantly. In addition, it must be remembered that most of these shell lines are handled by women or pre-draft age boys. The natural result of this situation has been the development of a large number of special handling devices, including lifts, transfers, hoists and conveyors to cope with the problem.

This specialized handling job has by no means been the only direction in which new developments have been made. The control systems on overhead handling devices, always a fertile field, have been further refined in the past year to increase speed, safety and flexibility. To handle heavy loads over long distances at low speeds, a new hoist controller has been developed. It is a selective system, giving dynamic control for contra-torque lowering to meet all requirements. For handling loads, including light loads which do not overhaul, the controller allows lowering at full speed with slow-down and accurate inching for landing the load with dynamic braking. For handling heavy loads at reduced speed through long distances, the operator pushes a push-button in the handle of his master switch which instantly converts the controller to contra-torque lowering connections.

Another new electric hoist drive for cranes, the important feature of which is an exciter embodying a cross-flux principle, has been developed recently. The new drive system not only automatically weighs the load so that it is hoisted and lowered at the maximum safe speed, but also it prevents handling dangerous overloads. Although the new system is not advocated for use in all types of cranes, it is particularly applicable to important cranes requiring the utmost safety in hoisting and lowering heavy loads, combined with high speeds when handling light loads and the empty hook, such as applications encountered in the average steel mill.

The problem of handling hot metal quickly and safely



The use of controlled furnace atmospheres has increased, and scaling and decarburization thus markedly reduced even over extended heating cycles.

is always a difficult one, and hot metal transfer cars are constantly being redesigned to help solve it. One of the newer jobs designed for use with an electric locomotive is equipped with a cab for the operator, containing a separate controller so the operator can be at the head of the train regardless of the direction it is traveling. The unit is of all-welded construction and the ladle is mounted on forged steel trunnions. The controller is a duplicate of the locomotive controller, and is connected by a 19-wire cable to the locomotive.

Insulating refractories in very large sizes givefast, eocnomical installation with a minimum of joints.

The use of stronger windings in lifting magnets has given good operating results in a number of plants. They have demonstrated advantages in handling coils having uneven tops, in loading scrap into charging boxes, in handling pig iron, billets and ingots, and with the use of a thermally insulated bottom, in handling hot materials. These extra strength magnets may be built in smaller sizes for a given lift, or, for a given size, will take larger lifts.

MECHANICAL DEVELOPMENTS

Advances in casting technique have resulted in new precision in high strength castings, completely free from flaws. This has made it possible to cast to close shape many precision steel products which formerly required heavy volume of machining. Tool steels in a wide variety of analyses are now being cast to shape for a wide range of applications, such as dies, forming tools, glass molds, gages, hobs, cams and the like, with pronounced savings of time, labor and material. Such castings require only a minimum of machine finishing, and are furnished in the annealed condition so as to minimize machining difficulties.

A recent development in boiler water conditioning uses synthetically produced chemicals to form an antifoam or "smooth boiling" treatment, superior and more effective than old type treatments based on the use of castor oil. Tests have shown the new material to be especially advantageous in steel plant boilers where the load fluctuates rapidly. Carryover from frothing, foaming, or violent boiling is materially reduced. Yard locomotives are also benefited by this treatment, particularly when irregular blowdowns do not permit proper control of solids in the boiler water.

Use of metal spraying for repair and maintenance work where tensile strength is not a factor has been gaining wider acceptance. The process requires proper technique and its application is limited, but used properly it has become an accepted maintenance tool and has resulted in considerable salvage.

Containing no moving parts, and requiring no cocks, traps or shutoffs, a device has been developed to remove automatically and continually all condensate from compressed air or gas lines. The device uses two porous ceramic tubes, one inherently water repellent, the other water-permeable but air-impervious. The air or gas first passes through the water repellent tube, a coarse ceramic material averaging 50,000 pore openings per square inch, where the moisture coalesces on the surface, then drops to the bottom of the unit and passes through the second tube, which is made of microporous porcelain, averaging 720,000,000 pore openings per square inch. Since air will not pass this tube, no pressure is lost.

While these units have to date been developed only in the smaller sizes (up to 1¼-inch pipe diameter) other units are now being perfected to handle greater capacities. With the huge quantities of compressed air used in steel plants and the great amount of trouble caused by moisture in the air, the usefulness of these devices is immediately apparent.

Another development announced during the year is the air-cooled worm gear speed reducer, wherein air from a fan mounted on the worm shaft is circulated over the outer ribbed surface of the oil reservoir. With this forced cooling it is possible to transmit twice as much power for a given size of reducer at usual motor speeds.

A double coupler device has been applied to a diesel-electric locomotive so as to permit switching both

This installation is the first twin motor drive to be installed on a plate mill, although the idea has been used on slabbing mills for some years.

standard railroad cars and special mill equipment. Using the device, one locomotive can handle different types of cars which might otherwise require separate haulage equipment. In this new design, two couplers of the friction draft gear type are mounted one above the other. The top coupler is set at the standard 34½ inch height, while the bottom is at 19¾ inches. Both couplers are worked by the same handle. Either coupler may be swung aside to permit the other to work singly. This combination design offers savings in rail power equipment, time and manpower.

An operating valve which is finding wide acceptance in war plants uses a reversible rubber seating element capable of absorbing foreign particles in the water which otherwise might hold the valve open and permit erosion of the valve seat. Another feature of these valves is the fact that all parts can be removed from the cylinders and replaced without disconnecting the piping. Hence, maintenance on these valves is quite low. Valves of this type are made in a wide range of sizes and types which cover almost any application in the steel plant.

The addition of extreme pressure additives to oils makes it possible to use lighter bodied lubricants where desirable and still carry heavy loads without breaking down. A series of ten new lubricants, varying in viscosity from 300 seconds Saybolt universal at 100 F to 970 seconds Saybolt universal at 210 F. These products are resistant to oxidation and thickening at elevated temperatures, and are highly resistant to foaming. The properties are obtained through the use of special extreme pressure additives and a lead soap developed for the purpose.

A series of steel mill greases testing well over 60 on the Timken machine have been introduced for heavy duty bearing applications. Exceptional adhesive qualities are combined with the extreme pressure characteristics to make for lower operating temperatures and longer roll neck life.

Several companies in the past year have brought out new lines of mill lubricants with additives which act as rust inhibitors without increasing oxidation, foaming or the production of oil-water emulsions. Use of these oils has been found highly successful, particularly in applications calling for intermittent operations, where bearings showed rust during the down periods.

Great strides have been made over the past few years in rust preventives necessitated by our extensive shipments of machines and component parts over the entire world. Ocean voyages and climates ranging from arctic to tropical quickly showed the need for perfect protection. Ordinary lubricating oils and greases are not suitable for rust preventives for any length of time because of their inability to thoroughly wet the surface and form an effective moisture barrier. Combinations of various compounds are usually resorted to, so that an adhesive protective film is present at all times. Different grades of rust preventives are available for the many applications, ranging from a light viscosity fluid used as a primary coating or for coatings for brief storage indoors, to a heavy grease-like substance intended for an enduring coating for exposed surfaces. An essential point in rust preventive selection is its ease of removal under the conditions which will prevail at the point of removal.

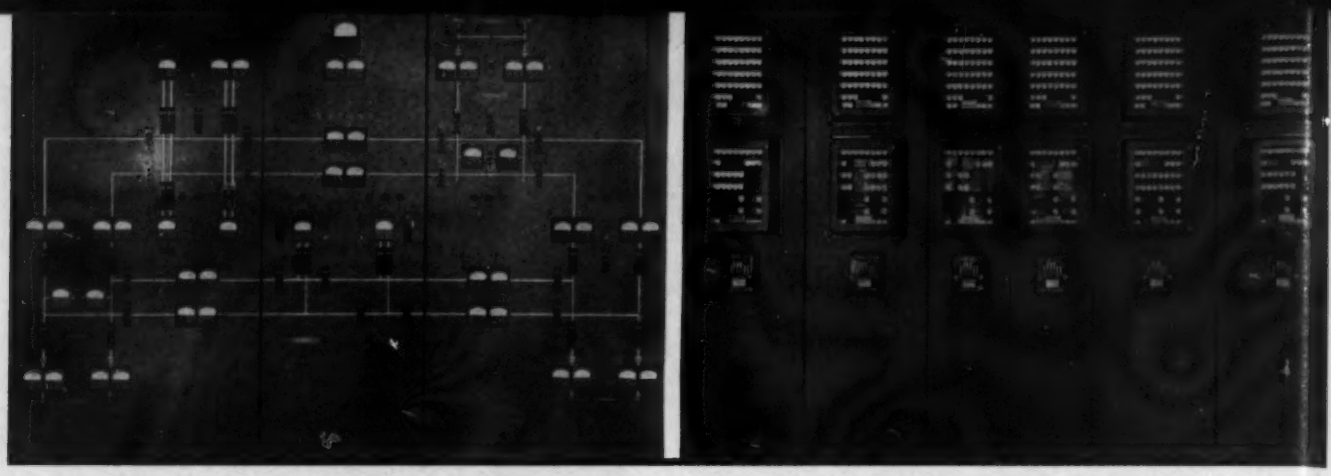
Electronic speed regulators, of extreme sensitivity, wil automatically hold motor speed constant at any preset value.

ELECTRICAL DEVELOPMENTS

With the great rush of the capacity expansion over, steel men are deeply engrossed in reviewing operations with a view to modifications to be made in the post war era. During the drive for production, there has been considerable interest in methods of increasing the capacity of existing drives, and this trend can be expected to continue. Likewise, it seems evident that there will be great activity in new designs and in the rehabilitation of old equipment to further the economy of production.

The past year witnessed the completion and starting of almost all of the new mills in the United States. Most of the new mill drives now under construction are for foreign delivery or for non-ferrous mills. Several unusual developments, however, are to be noted in main roll drives. A twin double armature drive rated at 12,000 hp, 70/140 rpm, was designed with a very low armature WR^2, as a replacement for a steam engine driving a record-making blooming mill. In order to take full advantage of this motor design, a motor-generator set was also designed, using low voltage fields and laminated field structures so as to obtain fast voltage reversal. This combination can equal the 100 rpm per sec rate of acceleration and deceleration of the steam engine and also provides a materially greater torque.

Another unusual drive going into operation last year is a twin-motor installation on a four-high 160 in. plate mill. Although previously used on large slabbing mills, this is the first application on a plate mill. Operating



Typical dispatching board for supervisory control of steel plant power system. Front view is shown at left, rear view at right.

experience has shown that the two motors are synchronized closely enough to meet all requirements. Smooth operation is obtained with little backlash and there is of course no possibility of having pinion marks on the plate.

Faster operations on temper mills have made news during the past year, and in one case the installation of new electrical equipment raised the top speed from the original 1565 fpm to a present 3300 fpm.

A trend is noted toward the production of very thin strip. One plant is regularly producing strip 13 in. x .0015 in. on a reversing cold cluster mill. Operations of this nature require very accurate control of the mill over the entire speed range to avoid tearing the thin strip.

The auxiliary regulating exciter of special characteristics has, under several trade names, continued its path of acceptance in an ever widening field of applications of variable voltage control. One new application is the ingot buggy, where the smooth, uniform application of torque permits maximum rates of acceleration and deceleration. The device is said to increase operating speed, while the size and number of control units are reduced, with corresponding reduction in maintenance and delays. One installation of this type is provided with a photoelectric signal system so that the pulpit operator can easily bring the buggy to the proper loading position. A second installation has magnetic limit switches which function to move the buggy automatically to the preselected loading position.

Other applications include reversing motor drive controls on blooming, slabbing and plate mills, speed regulation, flying shear synchronization and gauging, adjustable voltage drive for the thrust block of piercing mills, adjustable voltage control for drawbenches, adjustable voltage controls for mill tables, screwdowns and sideguards, electrode control for arc furnaces, tension controls, and many miscellaneous uses.

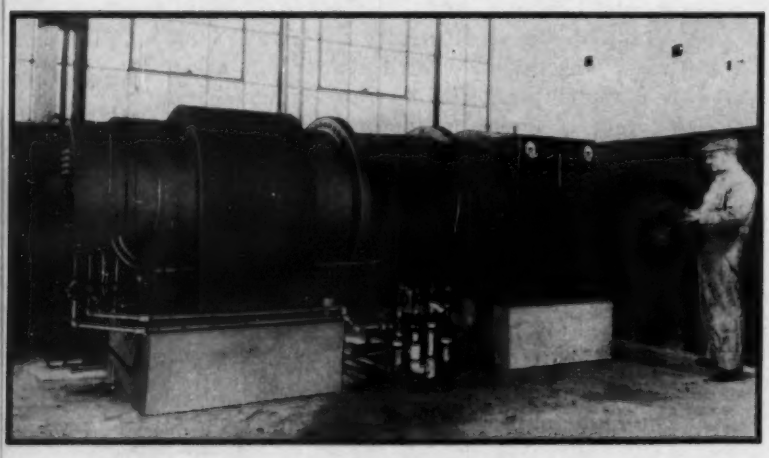
The growing use of electronic controls is to be noted from the various announcements over the past year, and it is safe to say that their application will grow, perhaps, under the impetus of current publicity, even to ill-advised uses.

A novel wire drawing equipment is being built which involves a 40 hp, 690/1380 rpm motor, which is controlled during acceleration and deceleration with voltage maintenance and current limit features provided by electronic equipment.

There has been considerable activity in connection with various types of processing lines, including shearing, trimming, slitting, pickling, galvanizing, cleaning and plating lines. A new type of reel alignment control has been developed using the transmitted light system rather than the reflected light system. In connection with two tinning lines, speed regulators employing auxiliary exciters of special characteristics have been added for maintaining constant strip speed in the plating sections, regardless of external factors. There has also been developed an electronic system for continuously recording plating thickness, based on speed of the strip and volume of the plating current. A new supersensitive pinhole detector will detect 5 mil holes at 600 fpm. It operates with a much narrower beam of light than older models, and the light intensity has been increased and applied through an improved optical system.

Two installations of supervisory control for the power system were made in steel plants during the past year (Iron and Steel Engineer, March, 1944). One installation is used to control the 22 kv distribution system. Feeders from two power houses, outgoing

Typical motor generator set of 500 kw capacity for supplying 3000 cycle current for induction heating.



feeders to three adjacent plants, and six plant substations are all controlled from a central dispatcher's station. The second installation provides complete supervision and control of all the main circuits of a large plant. This plant has eleven substations in addition to a main incoming station. All stations are unattended and all power, a-c and d-c, as well as the rotating equipment for main drives and auxiliaries, are under the control of the dispatcher.

Although not a new idea, dry type transformers have come into more general use during the past few years and are now available in capacities up to 7500 kva, with voltages up to as much as 15,000 volts. The use of class B insulation permitted such units to be designed for a temperature rise of 80 C, and recent development of resin impregnation of windings, together with ceramic wire coatings, may permit even higher operating temperatures. Smaller sizes of dry type transformers are usually totally enclosed so as to be drip-proof and weather resistant. Large sizes are generally equipped with forced cooling, using a blower and an air filter.

The growing acceptance of rectifiers has resulted in a marked increase in installations, both for general purpose 250 volt d-c power supply and for 600-700 volt d-c for adjustable speed mill drives. The 7000 kw unit which is to operate in parallel with motor-generator sets for supplying power to a hot strip mill has not yet been put into service.

The 20,000 kw electronic frequency converter for the interchange of power between 25 cycle and 60 cycle power systems is now in operation and has met all expectations. A paper dealing with this installation is published in this issue of the Iron and Steel Engineer.

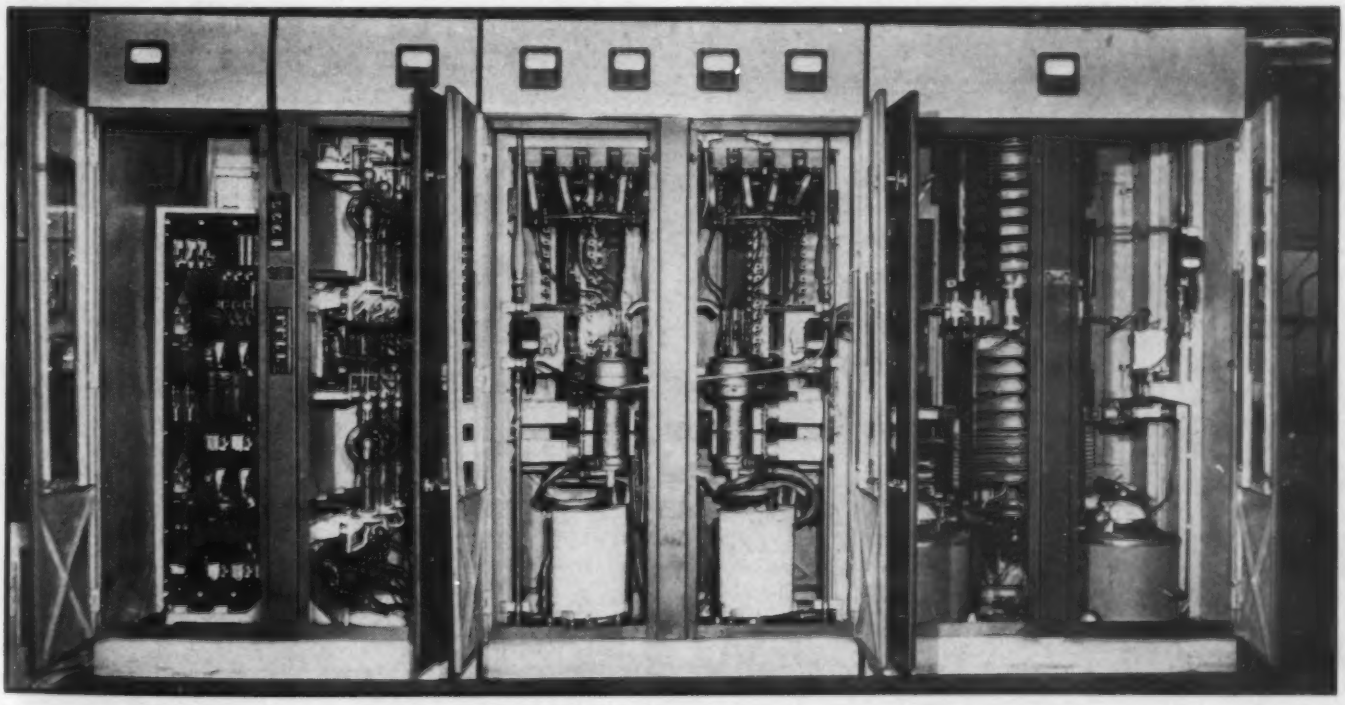
A considerable extension of storage battery life is promised for units using fabricated glass tape insulation to completely encase the positive plates. The tape is wrapped around the plates in a double layer, and is said to have better retentive power in holding the active material in the plate than does the standard glass mat. Also, by completely encasing the grid frames the rate of peroxidation of the grids is decreased. Both of these developments contribute to longer battery life, and the new design has shown about 30 per cent longer life in both laboratory and field tests.

As a result of experience with many installations during the past few years, considerable improvement has been made in air conditioning units for crane cabs and pulpits. Recent models emphasize speed of installation, simplicity, efficient performance, accessibility, and low maintenance. Units are so designed as to meet practically every condition of installation. Interest in air conditioning has mounted steadily, and the equipment is being used by steel mills, foundries, forge shops, nickel and copper reduction plants and wherever excessive temperature, gas, smoke and vapors combine to make working conditions unbearable. The units completely filter smoke, vapors, gases and dust from the air and deliver clean air, heated or cooled as needed, at a rate of one complete change per minute.

An improved design of combination service and parking brake makes the unit more compact and readily adaptable to the various types of industrial crane and transfer equipment. This brake provides foot controlled braking for service stops, spring set braking for parking, and automatic full load braking to bring the crane to a gradual stop in event of power failure or in case the crane is moved beyond desired limits. A compact hydraulic cylinder is used in the new design to release the parking brake in place of the solenoid previously used.

War conditions have placed an unprecedented load upon the carbon brush industry. Some manufacturers have had to increase output three or four times their normal production. In addition to this, considerable

Experimental oscillator of 200 kw capacity for very high frequency current to be used in welding operations.



research was required to keep up with the developments in electrical equipment. For example, literally thousands of motors are being built for 28 volts, which was practically unheard of before the war, and which requires new grades of brushes. Again, ordinary brushes were found to wear excessively when operated in airplanes at high altitudes. Here again, development work was required to develop a satisfactory brush.

A new instrument has been developed which detects differences in magnetic properties of ferrous material. Inasmuch as the magnetic properties of such material vary with the composition and hardness, the instrument is useful in checking composition, heat treatment, carburization, decarburization and the like. It is based on the principle that the inductance of an a-c coil depends on the permeability of the ferrous material of its core. If the permeability changes, the inductance changes. Thus, after calibration with two pieces of material known to be acceptable, an acceptable part is left in the coil of the instrument while the parts to be tested are placed, one at a time, in a second coil. A comparison of the two inductances thus shows any difference in the two parts. Of course the instrument will separate on the basis of a single factor only if all other factors are held constant.

Induction heating is being widely applied in heat treating, melting and forging operations. In some cases the demand for high frequency power has reached a point where such power is distributed from a centralized bus and as many as four 600 kw, 3000 cycle generators are operated in parallel. Further experimental work is under way with the view to the use of frequencies of 200,000-450,000 cycles, using oscillator tube generators.

ELECTRIC MOTORS OVER THREE HUNDRED HORSEPOWE

APPLIED TO MAIN ROLL DRIVES IN THE IRON AND STEEL AND ALLIED INDUSTRIES DURING 1944

Item	*Horsepower*	*Revolutions per minute*	*Volts*	*Frequency*	*Method of drive*	*Kind of mill*	*Purchaser*	*Location*	*Manufacture*
1	350	600	2200	60†	Geared	Merchant mill train	Mineracao Geral De Brasil, Ltda.	Sao Paulo, Brazil	General Electric
2	350	400/1150	250	d-c	Direct	Non-reversing cold strip mill	Revere Copper and Brass Company	New Bedford, Massachusetts	General Electric
3	350	375/750	230	d-c	Geared	Tube reels	Pittsburgh Steel Company	Allenport, Pennsylvania	Westinghouse
4	400	480/800	250	d-c	Geared	Steckel mill	Thomas Steel Company	Warren, Ohio	General Electric
5	400	480/800	2200	60†	Geared	Merchant mill train	Mineracao Geral De Brasil, Ltda.	Sao Paulo, Brazil	General Electric
6	400	720	2200	60†	Geared	Merchant mill train	Mineracao Geral De Brasil, Ltda.	Sao Paulo, Brazil	General Electric
7	500/150	600/231	440	50†	Geared	Merchant and bar mill	Fernando Garcia and Prudencio	Mexico	Westinghouse
8	500	514	4160	60*	Geared	Copper rod break-down mill	Riverside Metals Company	Riverside, New Jersey	Westinghouse
9	500	250/750	600	d-c	Geared	34 in. cold mill reel	Altos Hornos De Mexico, SA	Munclova, Conhuila, Mexico	General Electric
10	500	250/750	600	d-c	Geared	34 in. cold mill reel	Altos Hornos De Mexico, SA	Munclova, Conhuila, Mexico	General Electric
11	500	250/750	600	d-c	Geared	44 in. cold mill reel	Altos Hornos De Mexico, SA	Munclova, Conhuila, Mexico	General Electric
12	500	250/750	600	d-c	Geared	44 in. cold mill reel	Altos Hornos De Mexico, SA	Munclova, Conhuila, Mexico	General Electric
13	500	575/1150	600	d-c	Geared	Sendzimir mill	Revere Copper and Brass Company, Dallas Works	Chicago, Illinois	Allis-Chalmers
14	500	514	2200	60*	Direct	Tube rolling mill	Globe Steel Tubes Company	Milwaukee, Wisconsin	Allis-Chalmers
15	600	720	2300	60*	Geared	Copper rod mill	General Cable Company	Rome, New York	General Electric
16	600	720	2200	60†	Geared	Merchant mill train	Mineracao Geral De Brasil, Ltda.	Sao Paulo, Brazil	General Electric
17	600	600	2200	60†	Direct	Non-reversing brass mill	American Brass Company	Torrington, Connecticut	General Electric
18	1250/625	720/360	2300	60*	Geared	Brass piercing mill	Revere Copper and Brass Company	Baltimore, Maryland	Westinghouse
19	1250	600	4000	60*	Geared	2-high cold break-down mill	Bristol Brass Company	Bristol, Connecticut	General Electric
20	1500	500	2200	25*	Direct	Piercing mill	American Brass Company	Buffalo, New York	General Electric
21	1500	200/400	600	d-c	Direct	34 in. reversing cold mill	Altos Hornos De Mexico, SA	Monclava, Conhuila, Mexico	General Electric
22	1500	150/300	600	d-c	Direct	44 in. reversing cold mill	Altos Hornos De Mexico, SA	Monclava, Conhuila, Mexico	General Electric
23	1750	120	2200	60*	Direct	Piercing mill	Globe Steel Tubes Company	Milwaukee, Wisconsin	Allis-Chalmers
24	3000	175/350	600	d-c	Direct	56 in. hot strip mill	Steel Company of Canada	Hamilton, Ontario, Canada	General Electric
25	3500	150/300	600	d-c	Direct	56 in. hot strip mill	Steel Company of Canada	Hamilton, Ontario, Canada	General Electric
26	3500	170/350	600	d-c	Geared	56 in. hot strip mill	Steel Company of Canada	Hamilton, Ontario, Canada	General Electric
27	3500	170/350	600	d-c	Geared	56 in. hot strip mill	Steel Company of Canada	Hamilton, Ontario, Canada	General Electric
28	3500	170/350	600	d-c	Geared	56 in. hot strip mill	Steel Company of Canada	Hamilton, Ontario, Canada	General Electric
29	3500	170/350	600	d-c	Geared	56 in. hot strip mill	Steel Company of Canada	Hamilton, Ontario, Canada	General Electric
30	4000/2000	514/257	6600	60*	Geared	Seamless tube piercing mill	Pittsburgh Steel Company	Allenport, Pennsylvania	Westinghouse
31	7000	0/40/100	700	d-c	Direct	44 in. blooming mill		Russia	Allis-Chalmers

*Synchronous †Induction

Company	*Location*	*Type of mill*	*Number of motors*	*Total horsepower*
Altos Hornos De Mexico, SA	Munclova, Conhuila, Mexico	34 in. cold mill	3	2500
		44 in. cold mill	3	2500
American Brass Company	Buffalo, New York	Non-reversing brass mill	1	600
	Torrington, Connecticut	Piercing mill	1	1500
Bristol Brass Company	Bristol, Connecticut	Two-high cold breakdown	1	1250
Fernando Garcia and Prudencio	Mexico	Merchant and bar mill	1	500
General Cables Company	Rome, New York	Copper rod mill	1	600
Globe Steel Tubes Company	Milwaukee, Wisconsin	Piercing mill	1	1750
		Tube rolling mill	1	500
Mineracao Geral De Brasil, Ltda.	Sao Paulo, Brazil	Merchant mill	4	1750
Pittsburgh Steel Company	Allenport, Pennsylvania	Piercing mill	1	4000
		Tube reels	1	350
Revere Copper and Brass Company	New Bedford, Massachusetts	Non-reversing cold strip mill	1	350
		Sendzimer mill	1	500
		Brass piercing mill	1	1250
Riverside Metals Company	Riverside, New Jersey	Copper rod breakdown mill	1	500
	Russia	44 in. blooming mill	1	7000
Thomas Steel Company	Warren, Ohio	Steckel mill	1	400
Steel Company of Canada	Hamilton, Ontario, Canada	56 in. hot strip mill	6	20,500

Types of motors purchased	*Number motors*	*Total horsepower*
Alternating current motors	14	14,200
Direct current motors	17	34,100
Total	31	48,300

THE *Iron and Steel* INDUSTRY ON THE *Niagara Frontier*

. . . . though not a pioneer in the American iron industry, the Niagara Frontier now has a considerable steel capacity, including some outstanding examples of modern plant design . . . .

by E. F. ENTWISLE

GENERAL MANAGER

BETHLEHEM STEEL COMPANY

LACKAWANNA, NEW YORK

▲ FOR the purposes of this discussion, the Niagara Frontier is the area bordering the Niagara River and the eastern end of Lake Erie, and located in Erie and Niagara Counties of the State of New York. It embraces about fifty miles of shore line with Buffalo at the approximate center. The district can make no claim to pioneering the iron industry on the American continent, for Buffalo, as a white settlement, did not exist until after the War for Independence, and such iron production as the colonies boasted at that time all came from the eastern seaboard. Buffalo was not settled by other than the Indians until 1784 and history does not record that any attempts were made to establish the iron industry here until many years after that date.

Buffalo's development as an important point in the growing young Republic sprang from the fact that it was the eastern terminus of navigation on the Great Lakes, and, naturally, a transfer point for much trade between the east and the west. That it was recognized as the best route to the west was attested to by the construction, in 1825, of the Erie Canal, a monumental achievement of its time. This added substantially to Buffalo's advantages as a trading center and it rapidly became a major transfer point of immigration and commerce.

The pioneers in railroad building were quick to recognize Buffalo's advantageous trading position and the first railroad was built in 1836, and the Frontier soon became a year round commerce center. The first grain elevator was built in 1842 and since those early dates, when a half million bushels of grain were brought here annually by water, this commerce has grown to over 300,000,000 bushels, handled by eighteen mammoth elevators and eleven major trunk line railroads. Today, Buffalo's fine harbor handles upward of 20,000,000 tons annually.

Such a trading center naturally attracted to it correlated manufacturing enterprises but steam transportation and milling are still the Frontier's major peacetime industries with Buffalo often referred to as the largest milling and second largest railroad center in the country.

Of major importance in the development of other manufacturing industries on the Frontier were the discovery of the enormous ore supply of the Lake Superior region in 1844 (although not utilized to a great extent for many years), and the development of electric power from Niagara Falls in 1896. There are 340 industries classified as manufacturing in the United States and more than 70 per cent of this number are among the normal peacetime activities of the Frontier.

Against this briefly described background of the natural general development of the Frontier, let us place

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the pattern of the development of the iron and steel industry here. The location, measured in the terms of 19th century requisites for a profitable iron business, was not a "natural." None of the major materials needed, other than limestone, existed in the vicinity. The successful plants were those located immediately adjacent to either the ore or the fuel, or both. The Frontier lacked both, and while there was a market here for iron and steel products, created by the growing railroad and lake vessel building and the flow of commerce through the port of Buffalo — and while for a period in the '60s and '70s Buffalo's iron mills were well known throughout the country — the Frontier did not prior to 1900, make a spectacular contribution to the steel industry such as was made by, for example, Pennsylvania.

Nevertheless, there were pioneers who took advantage of the market created here for iron and with the advantages of lake, canal and railroad transportation for both the assembly of raw or semi-finished materials and the distribution of finished products, built plants that contributed substantially to the development of the iron industry and to the development of the country.

History records the ventures of many companies that took a part in the various phases of the metals industry and trade here, but to six larger interests, three of which were concerned principally with iron and three with steel, must go the principal credit for the development of the industry on the Niagara Frontier. In tracing the accomplishments of each of these separately, a certain sense of continuity is lost as compared to a purely chronological recital of events, but I believe the overall picture is somewhat more interesting when put together by the first method.

Probably the most colorful, and certainly the ones that have continued through the longest period, are the activities of the Pratt and the Letchworth families. The Pratt family came to Buffalo very early in its history and members of the family took prominent parts in the development and administration of the growing settlement. From the third generation of the family came Samuel F. Pratt who in 1822 entered the hardware shop of his cousins, George and Thaddeus Weed. By 1831 the company became Weed and Pratt. In 1836 Pratt bought out the Weed interests and took his younger brother, Pascal P. Pratt, into partnership. In 1846 Edward P. Beals became a junior partner and the name of the firm Pratt and Company. Their early business was principally as importers and dealers in hardware and metals. They traded in bar iron, sheet iron, railroad and contractors supplies, wire, farming implements, coach and saddlery ware and mechanics tools. The company ranked second in the country in volume of iron trade and was considered the largest hardware store in the world.

In 1848, Pascal Pratt persuaded William P. Letchworth, of New York, prominent in a firm engaged in the manufacture and sale of saddlery hardware, to come to Buffalo and in that year the partnership of Pratt and Letchworth was formed. The new company dealt solely with saddlery and carriage hardware and was organized as a separate business from the hardware store of Pratt and Company.

I have given this somewhat detail history because the activities of both Pratt and Company and Pratt and Letchworth were interwoven with many of the early activities in the use and manufacture of metals of the Niagara Frontier, and while some of the projects are listed under one name and some under the other, the interests generally were common and were a predominating influence in the development of the iron industry here.

Leaving the Pratt interests for a moment, history records that prior to 1826 a blacksmith shop was the only activity in the metal trades here other than merchandising. In 1826 Beals-Mayhew Company built the first iron foundry and machine shop. In 1838 the Justin Forge was built at the Black Rock Dam. In 1841 the Buffalo Engine Works was built to produce steam engines for lake boats.

In 1846 the Buffalo Rolling Mill and Iron Works was built by Corns and Company of Pittsburgh. The installation here was probably influenced by the large amount of metal business done by the Pratt interests, but there is little available history on the plant's first eleven years of operation. The mill manufactured nails and bar iron from puddled iron brought here from the east on the Erie Canal.

In the meanwhile, in 1848, the Pratt and Letchworth partnership had been formed. In 1849, the Howard Iron Works was organized and in 1850 the Niagara Forge, the second in the district, had been built. In 1852 the E. and B. Holmes Machine Corporation commenced the building of steam engines.

In 1857, Pascal P. Pratt purchased the Buffalo Rolling Mill and Iron Works, and in 1859 built an addition to it and changed the name to the Buffalo Iron and Nail Works. The additions not only increased capacity greatly, but included sixteen puddling furnaces — the first in the district. There were also nine heating furnaces, seven trains of rolls, fifty nail forming machines and a large blacksmith and millwright shop. These works were among the largest of their kind in the world at the time and employed about 500 men. They produced iron bars, nails, spikes, band iron and iron plate. They consumed annually about 14,000 tons of coal, 3000 cords of wood, 8000 tons of pig, scrap and bloom iron, and 600 tons of iron ore.

In 1854 Pratt and Letchworth had purchased the Buffalo Car Company (date of formation unknown) and converted the plant into an iron and brass foundry for the production of hames, saddlery and coach ware. In 1860 they built a second foundry adjoining the old one for the manufacture of malleable castings, a business in which they were pioneers. This venture was called the Buffalo Steel Company. In 1861 it produced the first crucible steel made in the district.

In 1863, Pratt and Company built the Fletcher blast furnace at Black Rock principally to furnish iron to its affiliates, the Buffalo Iron and Nail Works and the Buffalo Steel Company. It used anthracite coal for fuel, ore from McKean County, Pennsylvania, and produced 25 tons of pig iron daily. In 1881 the furnace was rebuilt and converted to the first coke-fired furnace in New York State. It was abandoned in 1885.

In 1872, Pratt organized the Niagara River Iron Company to build and operate a second Fletcher furnace near North Tonawanda. The furnace was blown in in 1873. The operation did not prove profitable and the furnace was shut down within a few years, remaining

idle until sold in 1889 to the Tonawanda Iron and Steel Company which added a second blast furnace in 1896.

Also abandoned in 1885 were the Buffalo Iron and Nail Works. It is recorded that labor trouble was the basis of the closing of these varied Pratt and Company operations, but it is likely that the principal reason for their abandonment was the growing use of steel.

Pratt and Letchworth foundry operations in the meantime had progressed steadily and in 1876 they produced the first open hearth steel in this district from a 15 ton acid furnace in their Buffalo Steel Company's plant. This was only eight years after the process had been introduced into this country. In 1908 two additional open hearth furnaces were installed.

Another important project originated by Pratt and Letchworth was the formation, in 1887, of the United Hame Company in order to segregate the production of hames, saddlery and coach fixtures from the foundry units. By 1897 this subsidiary dominated this line of business in the whole country and in 1902 the company reorganized into the United States Hame Company. This company manufactured 85 per cent of the hames produced in this country. The output in 1907 was about 2,000,000 pairs.

Let us go back again to 1861, two years before Pratt built his first Fletcher blast furnace. It was in this year that the Union Iron Company was organized, the first pig iron producer of the Niagara Frontier. This company shares with the Pratt interests the major credit for the development of the iron industry in this district. It built three blast furnaces, one in 1861, a second in 1862 and a third in 1865; also, in the period 1862 to 1865, puddling furnaces and rolling mills. The plant was an important one in its day, its products well known and in demand throughout the whole country. Its three blast furnaces could produce a total of 100 tons per day and its sixteen double puddling furnaces and its six rolling mills, 80 tons of finished products. These products were bar iron, plates, channels, beams, girders, shafting, rolled car axles and rails. History records in 1874 that for the previous two years this company produced 40 per cent of the rolled beams used in the United States. The company produced the first iron plates for ships on the Great Lakes. Up to this same year they had produced 20,000 tons of plates for this purpose and four such ships had been built in the company's own yards. The blast furnaces originally used Adirondack ores but later most of it came from the Lake Superior Region. Anthracite coal was used for fuel. Ownership of the company changed hands frequently in its early days, finally passing to the Lehigh Valley Railroad in 1872. In 1876 the operations of the furnaces and the mills were discontinued.

In 1892 the Buffalo Furnace Company was organized and purchased the abandoned plant, which was located on Hamburg Street in Buffalo. All of the old facilities were scrapped and the company started on the construction of three new blast furnaces. The first furnace, 80 ft high, with an 18 ft bosh, was coke fired, had an annual capacity of 80,000 tons and was blown in early in 1893. In 1899 the company was reorganized into the Buffalo Union Furnace Company and the second furnace, also of 80,000 tons annual capacity, completed and put into operation. In 1901 the company completed the third furnace, 60 ft high with a 15 ft bosh for the production of charcoal iron, annual capacity being 40,000 tons. This furnace continued on charcoal iron until August, 1904, when it was converted to a coke stack. The company continued operations at this plant until about 1930 in which year the project was abandoned and actually scrapped in 1937. In the meantime, in 1927, the company acquired the blast furnace properties of the Rogers-Brown Iron Company (about which more will be given later), operating the plant until 1930 when it was merged with the Hanna Division of the National Steel Company.

The third important pig iron producer appeared on the Frontier in 1902 when the Buffalo and Susquehanna Furnace Company was organized by local capitalists. The plant site selected was in the town of West Seneca near the new Lackawanna Iron and Steel Company plant that was then well under construction. The first furnace was completed and blown in in September, 1904, and the second furnace in July, 1905. In 1910 the Rogers-Brown Company acquired the plant and started construction on two additional furnaces, both of which

As the eastern terminus of the Great Lakes, Buffalo enjoys direct water shipment for its iron ore.

Comparison of this modern furnace with the first furnace built in the district 80 years ago gives striking evidence of the progress and development in the iron and steel industry.

were blown in in 1912. In 1920 the plant was leased to the M. A. Hanna Company which operated it until 1927. In that year it was absorbed by the Buffalo Union Furnace Company, which controlled it until 1930, when, as previously stated, the plant was merged with the Hanna Division of the National Steel Company, which still operates it.

Generally speaking, a line can be drawn through the year 1900 as separating the development of the iron industry on the Niagara Frontier from the development of the steel industry. It is true that Pratt and Letchworth produced steel here in 1876 but no addition had yet been made to that original installation. It seems strange indeed that with Buffalo's importance in the iron rolling business in the early seventies and with its steadily increasing pig iron production that no effort was made here to use the bessemer steel process that had been so rapidly expanded in other sections of the country in the period of 1865 to 1880. Why this should have been so I am not able to explain, but the fact remains that not until 1899, when the Lackawanna Iron and Steel Company decided to move their sixty year old plant from Scranton, Pennsylvania, where they had been making and rolling bessemer steel since 1875, did the steel industry come to the Niagara Frontier.

The industry's record here up to this time would not be complete if mention were not made of many correlated industries that have played an important part in the Frontier's development other than those already mentioned:

In 1858 the Buffalo Pitts Agricultural Company was organized to manufacture agricultural machinery.

In 1859 the Holley Manufacturing Company was incorporated for manufacturing steam pumps at Lockport.

In 1864 Farrer and Trefts Company was organized as a machine and boiler shop.

In 1870 the Westerman Rolling Mill was built at Lockport with two trains of rolls to produce bars and wire rods.

In 1872 the Sizer Forge Company was organized to produce large forgings from puddled iron.

In 1877 the Buffalo Forge Company was organized to produce car axles and forgings.

In 1889 the Snow Steam Pump Works started operation in Buffalo.

By 1894 four carwheel works and two car shops were operating in Buffalo and Depew: the Buffalo Car Wheel Company, the New York Car Wheel Works, the Niagara Car Wheel Company, the Union Car Company, the American Car and Foundry Company and the Pullman Company. Their combined annual capacity was 530,000 cast wheels and 11,000 cars.

In 1894 the Buffalo Bridge and Iron Works was organized for the fabrication of bridges.

In 1896 the Buffalo Bolt Company was organized for the manufacture of bolts and nuts at Tonawanda. This plant added a 14 in./10 in. bar mill in 1916 for rolling its stock from billets.

In 1900 the Buffalo Steel Company (not the Pratt and Letchworth foundry operations that had carried the same name) built a 14 in. rolling mill to produce angles, bars and shapes. In 1904 the plant started to roll T rails up to 30 lb per yard.

In 1902, the Snow Steam Pump Works combined with the Holley Manufacturing Company of Lockport and the latter plant was moved in its entirety to the Snow plant. In August, 1903, this plant placed a five ton side blown converter in operation. Here was made the first bessemer steel on the Niagara Frontier, preceding the Lackawanna Iron and Steel Company's production here by two months. In 1916 this company became part of the present Worthington Pump and Machinery Corporation.

In 1903 the Gould Coupler Company plant at Depew was built for the manufacturing of castings. Two 20-ton open hearth furnaces, with annealing and forging facilities were installed. Two additional open hearth furnaces were added shortly thereafter.

In 1904 the United States Tube Company was organized to manufacture charcoal iron boiler tubes $1\frac{3}{4}$ in. to 4 in. diameter.

In 1907 the Seneca Iron and Steel Company was organized to build the first sheet mills in New York State.

In 1908 the Strong Steel Foundry Company, with one six ton open hearth furnace, was started.

In 1909 the Corrugated Bar Company built a plant at Blasdell for the fabrication of concrete reinforcing bars. The plant was later acquired by the Kalman Steel Company.

In 1911 the Atlas Steel Casting Company was organized, and in the same year the Simmons Steel Saw Company moved their Chicago plant to a site near Lockport. Their operation included the making of crucible and electric furnace steel.

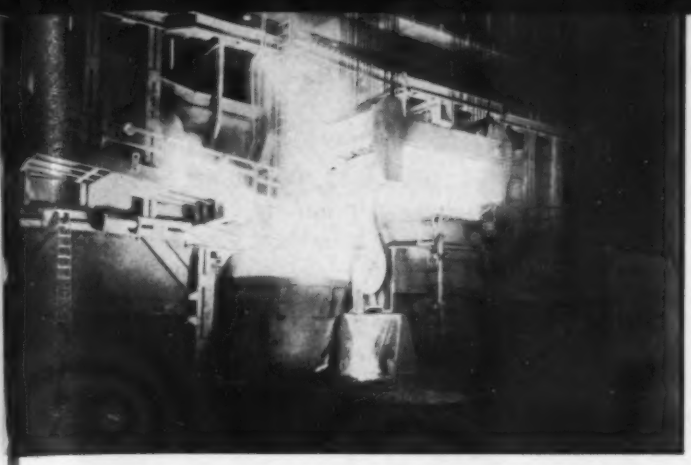
In 1918 the American Radiator Company built a small electric steel plant. This company in 1923 purchased the Tonawanda Iron and Steel Company blast furnaces from the Donner Steel Company, the latter company having acquired them in 1916. American Radiator dismantled the old furnaces and replaced them with a modern stack.

It will be noted that many of the concerns mentioned in this paper are foundries, and today the Niagara Frontier is recognized as the largest center of the castings industry in the country.

It is regretable that in this short review more emphasis cannot be put on the activities of the many other concerns related to the iron and steel industry that have contributed so much to the manufacturing progress of the Frontier. Important in this group are: The Acme Steel and Malleable Casting Company, American Brake Shoe and Foundry Company, The Buffalo Foundry and Machine Company, the Buffalo Pipe and Foundry Company, the Fillmore Foundry Company, the Lake Erie Foundry Company, the Pholman Foundry Company, the Washington Iron Works, the Lackawanna Steel Construction Company, the Buffalo Structural Company, the Buffalo Tank Company, the McKaig Hatch Company, the J. H. Williams Company, and the Bliss and Laughlin Company.

Returning to the period starting in 1900 when the steel industry as such, first came to the Niagara Frontier, there were three companies that have been responsible for the development of that industry here. In the order of their establishment they were:

1. The Lackawanna Iron and Steel Company (1900) with first production in 1903, now the Lackawanna Plant of the Bethlehem Steel Company.



The first open hearth steel was produced in the district in 1876 from a 15 ton acid furnace. Today, modern giants such as the one shown here maintain a constant stream of steel for armament.

2. The New York State Steel Company, first production in 1907, and now the Buffalo Works of Republic Steel Corporation.
3. Wickwire Steel Company 1907, first iron production in 1908, and now the Wickwire-Spencer Steel Corporation.

The Wickwire Steel Company was organized in 1907 by the Wickwire Brothers, wire manufacturers of Cortland, New York. The plant was to consist of blast furnaces, open hearths and finishing mills for wire products. The two blast furnaces, each with annual capacity of 150,000 tons, were blown in in 1908 and 1910. Not until 1916 was further construction undertaken, when plans were announced for the building of three open hearths, a blooming mill, a billet mill and a rod mill. These plans were gradually put into effect and in 1920 the company merged with the Clinton-Wright Wire Company forming the present Wickwire-Spencer Steel Corporation. Important additions were made to the plant in 1940 in the form of fine wire finishing units.

In 1906, the New York State Steel Company was organized. The plant was to consist of one blast furnace, two open hearths and rolling mills. The first steel was made in the new plant in April, 1907, although the blast furnace was not blown in until July, 1909. In 1915 the company was sold to William H. Donner, the name changed to the Donner Steel Company, and plans immediately announced for the construction of a second blast furnace, eight open hearth furnaces and additional bar mills. The new facilities were put into operation the following year. In 1920 the Donner and Hanna interests built 150 Kopper by-product coke ovens near the Donner plant. In 1926 the plant developed a method of die rolling for the production of preformed rolled sections and installed the necessary auxiliary equipment to properly carry on the large volume of this specialized business that resulted. In 1929 the Republic Steel Corporation purchased the Donner Steel Company and the plant, which specializes in the production of alloy, corrosion-resistant and carbon bars, is the present Buffalo Works of that corporation.

The most important decision in its effect on the iron and steel industry on the Niagara Frontier was made by the Lackawanna Iron and Steel Company to move its plant, started in 1840, from Scranton, Pennsylvania, to the shores of Lake Erie. The site selected and purchased in 1899 was in the town of West Seneca at the south end of the Buffalo harbor, now the city of Lackawanna. Construction started on May 29, 1900.

While the initial plans called for merely moving the old plant to the new site, construction had scarcely started before it was decided to build a complete new plant, the like of which had not yet been built anywhere. Here was a project that was to outstrip every previous effort in the steel industry, and lest I be accused of speaking from tradition handed down by word of mouth from those who took part in this undertaking, let me quote the opening paragraph of an article that appeared in the Iron Age on January 7, 1904:

"The greatest individual steel plant in the world is now approaching completion at West Seneca, New York, two of the blast furnaces, the great bessemer plant and the rail mill having been put in operation during the past year. Work is now progressing rapidly on four additional blast furnaces, on a second rail mill for light rails and splice bars, on a structural mill and on a very large slabbing and universal plate mill, and contracts have only been lately let for a modern bar mill and for six open hearth furnaces."

Many of the ideas incorporated in the building of the plant were new to the industry or to this country. Here was the first plant in America to use blast furnace gas engines to blow the furnaces and generate electric power. Here were the first regenerative by-product coke ovens. Here were many applications of electric motors to operations previously done only by steam engine or hydraulic power. Truly the men who built this plant, and it was less than half a century ago, were pioneers in the industry not only on the Niagara Frontier but in the world. Much of what they built has been superseded by still more modern equipment, but nevertheless they blazed the trails in many directions for those of us who came later.

A complete history of the construction and the early operation of the plant would prolong this paper to too great a length, but the importance of the undertaking to the Frontier and to the industry warrants a brief statement of the plant's facilities.

Two blast furnaces were blown in in 1903, and the bessemer and rail mill started operations on October 20, of that same year.

In 1904 seven batteries of coke ovens were started, also a third blast furnace, six open hearth furnaces, a 24 in. bar and shape mill, a 26 in. bar and structural mill, a 32 in. slabbing mill and a 48 in. universal plate mill.

In 1905 the fourth and fifth blast furnaces, a 12 in. bar mill and a 40 in. blooming mill were added.

In 1906 the eighth and ninth batteries of coke ovens, the sixth blast furnace and five additional open hearth furnaces went into operation.

In 1907 the tenth battery of coke ovens, the seventh blast furnace and an 18 in. continuous billet mill started.

In 1910 a twelfth open hearth furnace and a splice bar shop were completed.

In 1911 a 10 in. bar mill was started.

In 1912 the thirteenth and fourteenth open hearth

One of the largest mills in the country, this 54 in. reversing blooming mill serves primarily as a breakdown mill for a large structural mill.

furnaces and the first hot metal mixer went into operation.

In 1913 a spike, bolt and nut plant started, and the first two open hearth furnaces in a new open hearth plant made their first steel.

In 1915 benzol plants were placed in operation at the coke ovens and four additional open hearth furnaces started production.

In 1916 three more open hearth furnaces and a 16 in. bar mill began operations.

In 1917 the 10th furnace in the No. 2 open hearth plant started, completing this unit.

In 1918 two more blast furnaces were blown in.

In 1919 an 8 in. bar mill was placed in operation.

It is interesting to note from the foregoing that the plant had outstripped the original plans of its founders and had continued to grow in capacity as the years passed by.

Obsolescence and progress go hand in hand in the steel industry to a greater extent, perhaps, than in any other, and a year after this latest new mill was put in operation three of the original batteries of coke ovens were shut down for dismantling and a new battery of 60 ovens pushed its first coke. The following year a steam engine driving the roughing stand of the rail mill was torn out and replaced with the first large reversing d-c motor for a rolling mill drive in this country.

Thus, in 1922, we find the plant grown beyond the dreams of its founders, consisting of:

11 batteries of by-product coke ovens, three of which had been shut down for dismantling.
9 blast furnaces.
4 bessemer converters.
24 open hearth furnaces.
10 rolling mills (1 slab mill, 1 blooming mill, 8 finishing mills).
1 splice bar shop.
1 spike, nut and bolt plant.
1 fabricating shop.

In addition, there was of course all of the necessary auxiliary equipment of boilers, pumps, air compressors, repair shops, foundry, etc.

The capacity of the plant at that time was —

Coke	1,000,000 net tons
Pig iron	1,600,000 net tons
Steel ingots	2,060,000 net tons
Finished rolled products	1,500,000 net tons

The products were bessemer and foundry pig iron, bessemer and open hearth billets, sheet bars, heavy and light rails, structural shapes, sheet piling, splice bars, tie plates, rail joints, universal plates, merchant bars, shapes, railway spikes, bolts and nuts.

In 1922 the Bethlehem Steel Company purchased the entire interests of the Lackawanna Steel Company and immediately started on a program of reconstruction and additions to the plant. Too much time would be consumed in giving all the details involved in these changes. Suffice it to say that by 1931 most of the rolling mills had been replaced by new ones and a 48 in. wide flange structural mill added. No. 1 open hearth had been completely rebuilt, its 14 furnaces enlarged, the bessemer plant dismantled and construction started on a third open hearth plant of six 200 ton furnaces. All of the old coke ovens had been dismantled and replaced with three batteries of new ovens. Six blast furnaces had been torn down and one new one built. (The second new one was built in 1934.) Electric drives replaced steam engines on mill drives, and many other facilities contributing to better and more economical operations were added.

The Kalman Steel Company was purchased in 1931 and the Seneca Iron and Steel Company in 1932.

In 1936, a 79 in. continuous hot strip mill, and two mills for cold reduced sheets were put into operation — one of the finest and most modern installations of its type in the world. In 1937 the new open hearth plant, on which construction had started in 1929, was completed and new modern soaking pits replaced the old ones on the 44 in. blooming mill.

From 1938 to the present time two additional batteries of coke ovens have been built and three batteries completely rebuilt. Two of the largest blast furnaces in the world have been added, the old hot sheet mills at Seneca mechanized, a new galvanizing plant built, the old 12 in. bar mill completely rebuilt and moved to a new location for the rolling of alloy and carbon bars.

Thus today we find the Lackawanna Plant of the Bethlehem Steel Company one of the large, modern steel plants of the country with:

	Annual capacity
6 batteries of coke ovens	2,000,000 net tons
7 blast furnaces	2,550,000 net tons
30 open hearth furnaces (Basic)	3,120,000 net tons
3 blooming mills	
9 finishing mills	
1 continuous strip mill	

Total shipments on a normal peace time basis are 2,500,000 net tons and include structural shapes (standard and wide flange), sheet and Z piling, sheets (hot rolled, cold rolled and galvanized), plates, rails, splice bar and tie plates, bars (carbon, alloy and reinforcing), blooms, billets, slabs, fabricated structural material, fabricated re-inforcing bars, and miscellaneous fabricated sheet and bar products.

There is little of the original Lackawanna Plant or its service facilities remaining. One mill, built in 1904 is still in occasional use and the 10 in. and 8 in. bar mills,

(*Please turn to page 104*)

A History OF THE Iron and Steel Industry

. . . the history of the iron and steel industry is replete with evidence of the industry's profound influence on the industrial, economic, political and social development of nations and of the world . . . .

by F. C. FARRELL

DISTRICT MANAGER

REPUBLIC STEEL CORPORATION

BUFFALO, NEW YORK

▲ DEVELOPMENT of iron and steel may be generally classified into three main stages: the wrought iron period, the cast iron period and the steel period.

During the wrought iron period, which dates from at least 3000 B. C. to 1350 A. D., iron was obtained by mixing ore with charcoal which was burned under either natural or forced draft. For at least 4,350 years, the method of reducing ore and the quality of the product remained essentially the same, although some steps were taken to increase production. The first iron reduced from ore was probably obtained accidentally when fires were built against walls or beds of ore. This produced a spongy, viscous mass of iron which in some cases was 99 per cent pure but was more often mixed with 3 to 5 per cent of slaggy material which could not be entirely removed. The use of iron for weapons and ornaments is mentioned in several books of the Old Testament and iron blades have been found in Egyptian tombs erected about 3000 B. C. It is said that iron working was common in Greece about 2000 B. C. while other ancient peoples in India, Spain, and Italy used iron extensively. Romans invading Britain found iron making well established.

About 800 B. C. the production of iron had become an important industry in the ancient world. After the first discovery of iron, fires were built in windy places on ore beds to utilize draft in speeding the reduction process. Gradually it was found that ore and charcoal could be mixed together and ignited. Bellows, an early invention, were employed for forced draft and all of these steps led to the Catalan forge which was the main producer of iron up to 1350 A. D. This consisted of a hearth which was charged with iron and charcoal under draft from bellows and a short stack. The resulting iron was the same spongy pasty mass obtained by primitive people. Due to its comparatively high purity and to the lack of facilities for reaching high temperatures, this iron could not be completely melted, so that it was hammered or wrought by hand.

Steel was not unknown during this period. Ancients had found that after iron was reduced from ore it could be packed in charcoal and heated, with the result that a hard, springy metal resulted. The sword blades produced at Toledo and Damascus, which today are considered to be of exceptional quality, testify to the skill of steel makers in those days. Their process, which now is known as cementation, was still in use for producing steel early in the present century, and the present process of case carburizing utilizes the same principles.

Presented before A. I. S. E. Buffalo District Section Meeting, October 10, 1944.

However, the production of steel was comparatively small, since makers usually kept their processes secret and the quality of ore available in a given locality limited their success.

The cast iron period extended from approximately 1350 A. D. to 1856. It was found that if more than ordinary amounts of charcoal were mixed with ore and heated under draft, the iron reduced from ore was molten. This of course was due to introduction of carbon into the iron with resultant lowering of the melting point. As this became known, larger stacks were built on the Catalan forges and instead of charging all material on the hearth, ore and charcoal were charged in the stack. The reduction of ore was completed at the base of the stack and molten metal flowed into the hearth where it could be drawn off and cast into convenient shapes. However, this cast iron was brittle, whereas wrought iron was ductile. Therefore cast iron did not replace wrought iron but was used, with a great saving in labor, for articles which did not require great ductility and shock resistance. Furthermore, production of molten iron permitted heavier and more varied types of iron products than was possible with hand wrought iron. Thus, this forerunner of the modern blast furnace created another branch of the iron industry. Production of wrought iron continued to increase, while the secrets of making steel by the cementation process became more widely known, so that steel knives, armor, and various small weapons became more common. Already, the industry had three distinct and specialized branches which were exerting profound effects on the economic structure of the times.

After the first successful production of cast iron about 1350 A. D., demands for charcoal increased so greatly that in England, a major iron producing country, timber supplies became rapidly depleted. As a result Queen Elizabeth was forced to put drastic restrictions on iron production during her reign in the 16th century. Consequently, England found it necessary to import iron from Russia, Sweden, Germany, Belgium and Spain, all of which had vast timber resources at the time.

It is of special interest to note that Sweden, profiting from England's example, instituted a planned planting of timber to assure a constant supply of charcoal. This system, which still exists, together with an abundance of exceptionally high grade ore, enabled Sweden to maintain production of charcoal iron which became a standard of quality throughout the world.

About 1713, an Englishman named Darby discovered how to produce coke from coal and immediately recognized its value in the production of iron, since it provided a strong, porous, material for use in blast furnace shafts. This discovery revolutionized the iron industry and enabled the English to resume large tonnage production. By 1740, England not only had ceased all importation of iron but began to export to the continent and colonies.

In 1750, an advancement was made in steel making. The method of producing steel by packing wrought iron in charcoal previously described had many disadvantages, a principal one being that carbon from the charcoal penetrated only to a certain depth. This varied not only from piece to piece but within the same pieces, so that lack of uniformity was a problem. An Englishman named Huntsman found that if these carburized bars were placed in a refractory crucible they could be melted and poured into ingots or castings of uniform composition throughout. This process became the foremost means of producing high quality steel, and up until the early part of the 20th century, was the only means of producing high quality alloy steels. Although practically replaced by later developments of open hearth and electric furnaces, the crucible process still exists in almost the same form in which it was developed in 1750. It permits an extremely close control of chemistry and quality, but cannot be made economically in large tonnages.

In 1770 Watt's steam engine made its appearance and was utilized to drive the first rolling mill which was built in England in 1784 for the rolling of wrought iron into rough slabs which subsequently were worked by hand. Later, rolls were grooved to produce more definite shapes, and in 1835, steam hammers for forging were developed. By 1856 England had developed mills to roll the first armor plate for ships.

The puddling of wrought iron had been introduced in 1784. This was a method for refining of cast iron to remove silicon and part of the carbon. Originally the iron was melted on a hearth under a blast of air, but later a flux of iron oxide was added to form a slag and obtain a higher degree of refining. As the impurities were eliminated the metal became pasty and was drawn from the furnace in large lumps, cut into balls and squeezed in a press to eliminate some of the slag. As development of rolling mills continued, puddled iron was used for pipe and other purposes where its good welding properties and corrosion resistance were valuable. This process, introduced in 1784, was in widespread use early in the 20th century and appreciable demand for its product existed as late as 1929. Although no data on tonnages produced in recent years are available, it is probable that some puddling furnaces still operate at present.

The steel period began in 1856 with the adoption of the bessemer process. Although Sir Henry Bessemer profited greatly from the process given his name, it was not the invention of a single man. The original idea of this converter was not to make steel directly but to convert cast iron into wrought iron and subsequently make it into steel. William Kelly was the first to show that molten pig iron could be purified by blowing air through it and demonstrated this at Eddyville, Kentucky in 1847. In 1857 he built a tilting converter for the Cambria Iron Works, Johnstown, Pennsylvania.

Due to lack of financial backing, Kelly did not make a commercial success of his invention, but in 1856 Bessemer introduced and patented his process in England. After Kelly's original converter, one covered by bessemer patents was erected at Troy, New York, in 1865. The product of this and other units built in the same period was simply iron from which the impurities except phosphorus and sulphur had been removed. This iron was often red-short and hard to work. A Frenchman named Mushet suggested adding spiegeleisen to the molten iron after it was blown, with the result that added manganese reduced red shortness and carbon produced the necessary hardness. Thus the first means of producing steel rapidly and economically came into existence. However, the process had several disadvan-

tages. Original converters were lined with acid refractories and could not eliminate phosphorus, so that the resultant steel was hard to work unless it was made from iron having low phosphorus analysis, which in turn could be secured only from low phosphorus ores. Basic lined converters could reduce phosphorus but proved impractical for several reasons. The acid converter played a foremost role in supplying the needs of the rapidly expanding railroad industry and was the principal source of rail steel as late as 1905. The scarcity of low phosphorus ore as well as the development of the open hearth led to its progressive decline, but in recent years bessemer steel has found new applications and has been an important contributor to record breaking steel production in the present emergency.

In 1864, eight years after the first bessemer appeared, the English inventor William Siemens constructed a reverberatory furnace to produce cast steel. He obtained the necessary high temperatures by means of heat regenerators. The furnace was charged with iron ore and pig iron and produced a molten refined iron or steel. At the time he was developing this, a Frenchman named Martins experimented with additions of iron and steel scrap to the charge and this increased the adaptability of the process. These men had created the open hearth furnace, which was almost identical in design and general operation as the furnaces in use today. This furnace was lined with acid refractories so that elimination of phosphorus was the same problem encountered in the acid bessemer. Charges had to be made with low phosphorus material so that successful steel making depended upon availability of low phosphorus ore. However, within 20 years Thomas constructed a basic furnace in Brymbo, Wales. This permitted the use of basic materials to remove phosphorus and sulphur from iron or scrap, so that vast ore fields became useful for steel production. In 1908, open hearth production practically equalled bessemer output and since that year has become history's greatest steel producer.

As the open hearth was under development, interest was shown in producing steel by electrical energy. Iron was first melted by carbon electrodes in 1878, but nothing more was developed until 1892 when DeLaval patented his furnace for melting iron. The basic open hearth and the prohibitive cost of power caused the electric furnace to be neglected by the steel industry, although it was used for ferro-alloys, aluminum and calcium carbide between 1888 and 1894. A furnace was patented in Italy in 1898 for melting and refining steel. Heroult's furnace for steel making appeared in 1900 and shortly afterward, United States Steel Corporation secured patent rights and intensive developments in electric furnaces occurred between 1900 and 1915. The first furnaces used produced less than one ton per melt but improvements throughout the years led to furnaces which can produce 75 to 100 tons per melt. While the open hearth remains the large tonnage producer, foresight in developing electric furnace capacity and practice permitted the United States to meet the unprecedented demands for highest quality steels by the aircraft and other industries in the present war.

While this outline of development of iron and steel emphasizes the melting units, developments in mills, mining, and metallurgy were equally spectacular but are not so well defined in history, partly because changes were very gradual and often kept secret. The most spectacular developments have occurred since 1900.

On October 10th, 1944, the recently organized Buffalo District Section held its first regular meeting, with an attendance of 350 members and guests. The program for this meeting included papers by F. C. Farrell, of Republic Steel Corporation, and E. F. Entwisle, of Bethlehem Steel Company.

In reviewing the 6000 year history of iron these inventions are considered to be the greatest contributions to advancement:

	Year
Invention of coke	— 1713
Invention of the steam engine	— 1770
Invention of the rolling mill	— 1784
Invention of hot blast	— 1830
Invention of the bessemer converter	— 1856
Invention of the open hearth	— 1864

It is of interest to note that the reduction of iron from its ore without fusion as practiced by primitive people remains of important interest to the steel industry at present. If production of sponge iron can be achieved economically and in sufficient tonnages, it is conceivable that it may open a new era in the industry. The war has revived interest in this process to new heights and several units have been operated or are under construction for this purpose but as yet show no immediate possibility of replacing the blast furnace.

DEVELOPMENT IN UNITED STATES

Perhaps no nation on earth has been so greatly affected in its political, economic, and social history by the steel industry as the United States. The colonial period began late in the 16th century and ended with the Revolutionary War, thus running during the wrought iron period of iron and steel development. The first settlers of North America at Jamestown, Virginia, mined the first iron ore in 1585 and in 1608 had exported ore to England.

Early colonization was concentrated on the seaboard from Virginia up through Massachusetts. Iron ore of varying quality was found throughout this region and timber for charcoal was abundant. As a natural consequence it was common for individuals to make sponge iron which was then made into nails, small household implements, and tools. Entire families would spend parts of the winter in hammering nails and small implements from iron produced in the small farm forges.

Virginia had the means to become a leading iron producer but found tobacco planting more profitable and more suited to her climate. The New England colonies, with less varied opportunities in agriculture, became particularly active in iron production and laid the foundations of our present industrial system.

The Pilgrims landed in 1620, and by 1644 an iron works had been built at Lynn, Massachusetts by Governor John Winthrop. Connecticut followed closely and by the early 18th century was the leading producer of iron. In this colony many small forges existed, and there were steel makers in most communities to produce knives, sickles and similar articles. Iron was wrought into useful articles and sold to other colonies by the famous Connecticut peddlers. Iron works were built at Salisbury and Kent, Connecticut, about 1730, and Connecticut led in production until 1750 when Pennsylvania assumed leadership.

Abundance of timber led to early interest in ship building, especially since England was still suffering from a wood shortage. Shipyards were concentrated in the northern colonies and created a demand for iron nails, chains, anchors and similar fittings. This provided incentive for development of iron works and by 1750 the colonies were producing iron products of every kind but still depended on England for some steel products such as fine cutlery, needles, and special tools.

After the development of coke in 1713, England's iron industry was not handicapped by timber shortage and soon she was producing enough iron for export. As a result English ironmasters became alarmed at progress being made in the colonies and in 1750 induced Parliament to pass an act forbidding Americans from setting up mills to work bar and cast iron or produce finished iron articles. However, the sympathy of some English statesmen and royal governors together with difficulties in policing the colonies allowed the manufacturer of forbidden goods to flourish. This was fortunate, because the success of the colonists in the Revolutionary War was to depend greatly on the skill of American ironmasters.

Further laws were passed requiring all iron and other products produced by the colonies to be exported to England exclusively, for by this time American ships were finding their own markets while enjoying protection of the British fleet. These and similar restrictions on other products were loosely enforced even up to the opening of the Revolution when the colonies rebelled more against the principles than actual enforcement of such laws as the Navigation and Stamp Acts.

The opening shot of the Revolutionary War in April 1775 threw the colonies into a period of rapid industrial development. Imports were practically cut off since the British fleet ruled the seas. France had sufficient naval power to break the British blockade but, having suffered recent defeats from England, she was reluctant to resume war. It was not until 1778, five months after Burgoyne surrendered at Saratoga and almost three years after the war began that France gave the colonies military and economic assistance. During those first critical three years America's ironmakers supplied most of the weapons for Washington's army.

The iron and steel industry has a proud heritage in the political history of our country. Long before the Revolution, Puritan and other colonial leaders either owned or encouraged iron works. The Declaration of Independence was not merely what the name implies, but is considered to be one of history's most important documents concerning theories of government, society, and rights of man. Four of the men who assisted Jefferson in the final drafting and signing of the Declaration were ironmasters; 24 high ranking officers in Washington's Army were ironmasters. Paul Revere is most commonly remembered for his famous ride but actually, this was one of the least of his contributions to the political and industrial development of the colonies. Aside from being a respected political leader, Revere was the most skilled silversmith in the colonies and examples of his work have been preserved for the ages because they are classics of his craft. Revere was a descendant of Thomas Dexter who at one time had owned and operated the first iron works in the colonies at Lynn, Massachusetts. During the Revolution, Revere turned his practical genius to the production of cannon and shot. Under the guidance of a Frenchman named Ansart he was able to expedite the casting of these articles and

This old photograph, made at Canton, Ohio, in 1907 at the time of the pouring of the first open hearth alloy steel, was recently reproduced in "Republic Reports," published by Republic Steel Corporation. Left to right are: Peter Reese, F. M. Beckett, J. Kent Smith, M. Thompson, J. M. Flannery, C. Harold Wills, a Mr. Lenhart, Henry Ford, R. G. Lewis and F. J. Griffiths. The print belongs to Mr. Griffiths who resides in Massillon, Ohio. Mr. Lewis, now with Bethlehem Steel Company, helped identify the men.

relieve a serious armament shortage that was threatening Washington with defeat in 1777. Later he constructed a mill which produced the first rolled copper in the United States and was used to sheath the bottoms of warships, among them the famous "Constitution." This was the origin of the copper company which now bears his name.

The great efforts made by iron makers to meet war demands is well illustrated by the production of a chain weighing 180 tons. This chain was made of wrought iron bars 2½ in. square, shaped into 100 lb links and was nearly a mile long. It was completed in six weeks by 17 forges and 60 men working night and day. The finished chain, made entirely by hand, was stretched across the Hudson River near West Point and was supported by heavy timbers. This closed the river to British ships for invasion and landing of supplies in upper New York. The British succeeded in breaking it at one point but it was immediately repaired. Such projects as this spurred industrial development and established the ability of American ironmasters.

Pennsylvania made rapid strides in iron production immediately before and during the war and assumed the leadership about 1750. No production statistics are available for the colonial period. The small forges might produce 5 to 200 pounds of iron per day while the largest furnaces did not exceed 1½ tons per day as compared to the daily output of 1000 to 1500 tons from modern furnaces. Steel production was small and confined to special articles. In 1790, after a period of intense development there was ½ lb of steel in use for each of the 3,500,000 people in the states. Today each of our 130,000,000 people has command of 17,000 lb of steel exclusive of war material.

EXPANSION PERIOD

With the war ended and the colonies united, colonists began to move inland across the fertile lands of Pennsylvania, New York, and the Ohio Valley. Iron workers went with them and the first blast furnace west of the Alleghenies operated in Pittsburgh during 1790. In 1801 the unusually high grade ore of the Champlain district was developed and an iron works was built at Willsborough Falls, New York. By 1806 there were several furnaces in Ohio and in 1839 a blast furnace was erected in Illinois. This illustrates how closely iron and steel were associated with the needs of the westward migration.

Coke was first used by American furnaces in Armstrong County, Pennsylvania during 1819. However, charcoal remained important probably because the clearing of land provided an abundant and cheap supply of timber. It was not until 1855 that the consumption of anthracite coal by the iron industry exceeded that of charcoal, and anthracite retained the lead until 1874 when bituminous coal consumption exceeded that of anthracite. Pennsylvania had access to coal and ore deposits, particularly in the western sections, and played the foremost role in expansion of the industry. By 1850 New York and the New England states were reduced to minor producers, but these states had turned to manufacturing of finished metal articles and were important customers of the new iron and steel producing areas.

Almost all of today's major steel corporations had their beginning in Pennsylvania. The Lukens plant was built at Coatesville in 1810, and a furnace built at Sharon became the property of Republic Iron and Steel Company, later the nucleus of Republic Steel Corporation. Bethlehem turned out its first products in 1863 and in 1873 the Edgar Thompson works were built by Carnegie and McCandless. Carnegie later made extensive developments in the Pittsburgh area which, with the Illinois Steel Company, formed the major subsidiary of the United States Corporation.

Between 1810 to 1870 cast and puddled iron were leading products and found a ready market in the rapidly expanding railroad industry. In 1835 there were 23 miles of railroad in use which, with the increased supply of iron and steel, grew to 30,626 miles by 1865.

In 1844 a surveyor working in northern Michigan found that his compass was reading a full quarter circle off true north. Much annoyed, he searched for the cause and soon found what were literally mountains of almost pure iron. Some was exposed and in other cases the rich ore lay a few inches beneath the ground. This led to development of the great Superior ore region which can be mined with steamshovels. Attempts were made to set up iron works near the early mines but since the region was a wilderness it proved more practical to ship ore to mills at Pittsburgh, Cleveland and Chicago. By 1855 the Soo locks were completed and the Great Lakes ore traffic began.

The Civil War caused further development of the industry, particularly in Ohio and Illinois, while the South diverted more attention to iron works in Tennesseee

and Alabama. Efforts of northern iron producers and manufacturers to reduce the South's importation of metal articles from England and other countries in exchange for agricultural products was a major factor leading to war.

In 1867 there were three bessemers producing steel and in the same year the first steel rails were rolled commercially at Johnstown. However, the open hearth was soon in use. The first furnace was built at Trenton, New Jersey in 1868. This never operated successfully but in 1870 the Bay State Works in South Boston, Massachusetts put an open hearth into regular production. Both of these furnaces had acid lining and produced 5 to 7 tons per melt. In 1888 the first basic open hearth was installed at Homestead and a new era of steel making began.

At first the bessemer dominated the industry as a steel producer and from 1856 until 1870 was the source of all rail steel. Bessemer rails were still produced between 1915 and 1920. By 1878 the open hearth was making 26 per cent of the rail steel produced and was rapidly expanding. The introduction of the basic open hearth ten years later permitted this process to become the leading steel producer by 1905.

In the expansion era, annual production had increased from about 1,200 tons of steel in 1810 to 11,410,000 tons of bessemer and open hearth in 1900. During the same period, iron production increased from 80,000 to 17,300,000 tons.

THE MODERN ERA

For practical purposes, 1890 can be considered the start of the modern era of the iron and steel industry. This period has been featured by the continued development of open hearth and mill equipment, the production of alloy steels, invention and development of the electric furnace process, and great development of steel industry in the middle west.

Chromium had been used as an alloy in 1865 for various grinding equipment and the Eads bridge across the Mississippi which was built in 1874 contained considerable chrome steel. Tungsten was discovered accidentally in steel melted during 1868. Nickel was used purposely in armor plate for the navy in 1891 and had its first mass production application in bicycle chains. Steel containing 10 per cent was developed for steam shovel teeth in 1882, while silicon transformer steel was produced in 1889. Molybdenum did not attain widespread use as an alloy until the large Colorado ore deposits were developed in 1918.

At the time these alloys were first developed, the crucible process was the only means of providing the close control desired in alloy steel production. While crucibles produced 112,000 tons in 1900 and 125,000 tons in 1910 it was desired to find a method more suitable for large tonnnage production. The first electric furnaces had been introduced about the same time that alloys became known, and in 1900 produced 7 tons of steel. Refinements of design and developments raised production to 58,000 tons in 1910 and another peak of 596,000 net tons was reached in 1929. Continued development and expansion of this process permitted an output of 3,880,000 tons in 1943. The crucible process produced 2300 tons in the same year.

The open hearth has not been neglected by alloy steel makers. J. Kent-Smith made the first alloy steel by open hearth process at Canton, Ohio in 1907. This steel was sold to the Ford Motor Company which pioneered mass production use of alloy steels. In 1943, open hearths produced 9,221,000 tons of alloy steel, almost three times that from the electric furnace, but as yet the open hearth cannot be utilized for steels of high alloy content such as the 18-8 stainless type. The electric furnace is also preferred for consistently successful production of grades requiring unusually close control of chemistry and quality.

Today the United States steel industry produces about 45 per cent of the world's output and its progress can best be judged by the following statistics. In 1810 the nation produced about 1200 tons of steel or 374 pounds per hour. In 1943, production was 90,000,000 tons of ingots alone, an average of 10,274 tons or 20,548,000 pounds per hour. From 1900 to 1943 steel output was increased by 800 per cent.

It is clear that the present world owes much of its progress to the foresight and genius of American steel makers who even in colonial days exerted a powerful influence on the industrial, economic, political and social structure of the times. Today, the industry is in an expansion period on the West coast. This, together with continued development of alloys and electric furnace processes, may mark the beginning of a new era for the industry.

ENTWISLE *Paper*

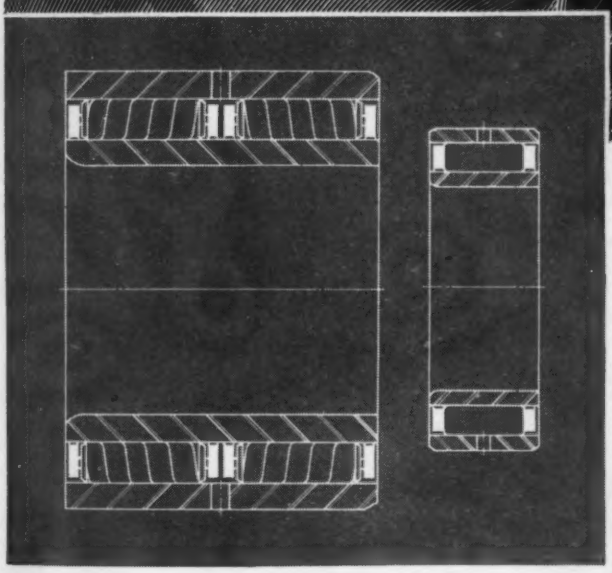
(*Continued from page 98*)

started in 1911 and 1919 continue to run regularly. Gone are those original gas engines, replaced with more modern ones or with steam turbines. Gone are all the old boiler plants, the newest replacement generating its steam at 850 psi pressure, superheated to 850 degrees. Gone is the bessemer. Gone are the first six blast furnaces. Most of the original service shops remain, but largely equipped with modern tools. Like the grandfather's razor that had had four new blades and two new handles but is still grandfather's old razor, the plant remains in outer resemblance, in part at least, much as it looked twenty-five to forty years ago, but unlike the razor, it is thoroughly modern in its equipment and practices and is proud of its record of contributions to the development of the Niagara Frontier.

And so ends my story. Undoubtedly there were others than those I have mentioned who made substantial contributions to the development of the industry here in the Niagara Frontier. I pay my deep respects to all who have had a hand in the progress that has been made. To me, this review is ample proof that the credit does not belong to any one man, or to any small group of men, or to any one period. It is typical of the steel industry that all who have worked and continue to work in it add to its progress. The last page in the history of the development of the iron and steel industry on the Niagara Frontier, and elsewhere, will only be written when steel and iron are no longer produced.

The Equipment that made 2 world records producing steel

BEARINGS: HYATT



Hyatt wound roller type as used in the table rollers. Hyatt 70,000 series solid roller type as used on line shafts. There's a size and type of Hyatt Roller Bearing for every application.

To a blooming mill that had established a world's record producing 171,440 tons of steel ingots in a month, was added more glory when 512 ingots were rolled by one of the three crews during an 8 hour turn.

Production like that would permit no time out for bearing wear or care, but this mill knew from past experience that with Hyatt Roller Bearings on all table rollers and line shafts all would be well, all the time.

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J. L. Miller, *president*

1945

ASSOCIATION

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STEEL

ENGINEERS

The President's Message

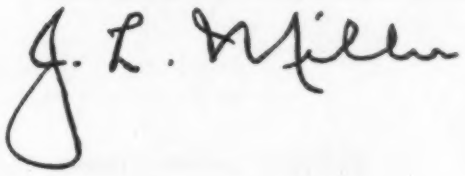
World War II has placed unprecedented emphasis upon the importance of the engineer and technician in both the industrial and the military phases of modern warfare. Even before the United States became actively engaged in World War II, one of the chief problems with which we were confronted was that of contributing to increase the Nation's production facilities.

In 1945 we will probably be faced with even greater complications. First, we must continue to produce at high speed in response to government needs. Second, the end of the European phase of the war, which we all hope will come early during the coming year, will find us with curtailed schedules. Third, we will be face to face with the problems involved in taking the first steps in a conversion program.

As engineers we must be in a position to furnish accurate technical data and information to our superiors. There will be no room for mistakes or errors of judgment.

Each one of us must look to the future with the full realization that his skill will be taxed as never before and that in this transition year we must shoulder more responsibility than we have ever shouldered in the past.

Sincere in the belief that the activities of the Association of Iron and Steel Engineers will help each one of us in meeting our new responsibilities, the officers and directors of the Association ask the earnest cooperation of everyone in carrying out its programs for the ensuing year.



NEWLY ELECTED A. I. S. E.

Officers and Directors

1945

J. S. MURRAY was educated in the Toronto, Ohio, public schools, Carnegie Institute of Technology, and the students course at Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania. Mr. Murray entered the employ of Westinghouse in 1916, in the research and sales department. He entered consulting engineering work at Pittsburgh in 1918. In 1920 he went with the Follansbee Brothers Company as chief electrical engineer. He has supervised the production, test and application of silicon steel sheets produced by the Follansbee Steel Corporation since 1932.

FREEMAN H. DYKE graduated from Phillip Andover Academy and from the Massachusetts Institute of Technology. Mr. Dyke started in the steel business with the Wheeling Steel Corporation at their Portsmouth plant in 1920, and with the exception of three years with the Jones and Laughlin Steel Corporation he has been with Wheeling Steel Corporation continuously. After serving in several capacities in various departments, Mr. Dyke became superintendent of the blooming, bar and hot strip mills at the Steubenville plant, and has recently been made assistant general manager in charge of steel works.

J. D. JONES, chief engineer of the Youngstown Sheet and Tube Company, Youngstown, Ohio, was born and reared in Pittsburgh and was educated at Pittsburgh Academy. From the outset he was interested in steel and set out to obtain a wide range of experience in the production of steel. He has worked in steel plants in Wheeling, Chicago, Buffalo, Pittsburgh and other cities.

In 1912, Mr. Jones went to Sault Ste. Marie as chief engineer of the Algoma Steel Company. In 1916 he went to the Gary works of the Illinois Steel Company as chief engineer until the latter part of 1919, when he returned to Algoma Steel Company as general superintendent later becoming general manager and vice president. He went to Youngstown Sheet and Tube in August, 1935.

A. J. FISHER was graduated from the Colorado State preparatory school and later from the University of Colorado, college of engineering, with a degree of M. E. in mechanical engineering. Mr. Fisher began his steel mill employment with the Bethlehem Steel Company at the Maryland plant as assistant master mechanic of the sheet and tin mill division in 1924. After serving in several capacities in various departments, Mr. Fisher became fuel engineer in 1929, holding that position at the present time.

C. H. WILLIAMS was graduated from the University of Colorado in 1926 and was employed by Jones and Laughlin Steel Corporation as shear foreman in their Pittsburgh plant. In 1927 he became a junior engineer in the power department of National Tube Company at Pittsburgh, shifting in 1930 to the Ohio Works of Carnegie Steel Company. Here he served successively as junior engineer, power and fuel engineer, and assistant chief engineer. In 1940 Mr. Williams was transferred to the Pittsburgh office of Carnegie-Illinois Steel Corporation as power and fuel engineer on the staff of the chief engineer, and was subsequently appointed assistant chief engineer of the Pittsburgh district. In 1941 he was placed in charge of a newly organized defense engineering staff to coordinate the engineering of defense steel plant expansions of the company in the Pittsburgh district. He was subsequently transferred to the United States Steel Corporation of Delaware as assistant to the vice-president of engineering, and in 1943 to chief engineer of the Pittsburgh district, Carnegie-Illinois Steel Corporation.

STANLEY GRAND-GIRARD was born at Circleville, Ohio, in 1890, graduating from Everts High School in 1908, and from Purdue University in 1912. He started with the Youngstown Sheet and Tube Company as inspector helper, advancing to the position of general electrical foreman of the coke plant. In 1917 he joined Republic Iron and Steel Company as assistant electrical engineer, remaining there until 1928, when he went with Sharon Steel Corporation, where he now holds the position of superintendent of electrical and mechanical departments.

J. H. MILLER worked for the Georgia Power Company from 1922 to 1929 in various capacities, from cooperative student to substation testing, obtaining a B. S. degree from Georgia Tech in 1927.

He then entered the test course of the General Electric Company at Schenectady and was transferred to the St. Louis service shop of that company in 1930. In 1935, he went to the Wisconsin Steel Works of the International Harvester Company as electrical draftsman, advancing to the position of assistant electrical superintendent in 1936, and electrical superintendent in 1939.

C. H. WILLIAMS
DIRECTOR AT LARGE

STANLEY GRAND-GIRARD
DIRECTOR

J. H. MILLER
DIRECTOR

T. C. MAYBERRY
DIRECTOR

J. S. MURRAY
FIRST VICE PRESIDENT

FREEMAN H. DYKE
SECOND VICE PRESIDENT

J. D. JONES
TREASURER

A. J. FISHER
SECRETARY

T. C. MAYBERRY began his career in 1920 in the cold strip department of the Greer Steel Company at Dover, Ohio, as a helper on the cold reducing tandem mill. In 1921 he went to Trumbull Steel Company, Warren, Ohio, where he worked as helper, roller, and turn foreman until early 1931. He then went to Wheeling Steel Company as general foreman of the cold reducing sheet mill department. In January, 1934, he was employed as superintendent of the cold reducing tinplate department of the Youngstown Sheet and Tube Company, Indiana Harbor Plant, being transferred in 1935 to the Youngstown, Ohio, Plant, as assistant superintendent of the cold reducing sheet mill. He next went to Great Lakes Steel Corporation in 1936 as superintendent of the cold reducing sheet mill. In 1940 he was appointed assistant general superintendent of the Great Lakes Steel Corporation, and in 1941 he was promoted to his present position as general superintendent.

F. C. SCHOEN was born in Cleveland, Ohio, in 1907, and in 1930 received a B.S. degree in Electrical Engineering from the Case School of Applied Science.

He was then employed by the General Electric Company, Fort Wayne, Indiana, as a student engineer, moving in 1933 to Republic Steel Corporation, Massillon, Ohio, as a motor inspector and advancing to the position of electrical maintenance foreman.

In 1938, he transferred to the Midvale Company, Philadelphia, as an assistant to the plant engineer, later being made master mechanic. In 1943, Mr. Schoen was given an M.S. degree in mechanical engineering from Towne Scientific School of University of Pennsylvania. During 1944 he was advanced to his present position as plant engineer of the Midvale Company.

L. R. MILBURN was graduated from the University of Michigan with a degree of electrical engineering in June, 1918. From July, 1918, until 1919 he went with the General Electric Company doing testing, complaint, installation, and apparatus sales work. In March 1925, he moved to the Louisville Gas and Electric Company where he did construction work until October, 1929, obtaining excellent knowledge of the working of the central station industry. Starting his steel mill career in October, 1929, with the Great Lakes Steel Corporation as electrical draftsman, Mr. Milburn remained in this position until 1933 when he was appointed acting electrical engineer. In 1935 he was promoted to electrical engineer.

PAUL J. BOWRON was graduated from Carnegie Institute of Technology in 1926 with the degree of B.S. in chemical engineering. He then entered the employ of Koppers Construction Company, resigning after two years to take a position with Tennessee Coal, Iron and Railroad Company at Fairfield Steel Works, in the steam engineering department. He then spent two years in the fuel engineering department, five years in the metallurgical department, and two years as general practice man at Fairfield Steel Works, being placed in the position of assistant superintendent of annealing when Fairfield tin mill was under construction in 1937 and advanced later to his present position as superintendent of the department.

J. H. VOHR was graduated from Cornell University in mechanical and electrical engineering in 1916 and became associated with the New York State Railways as an electrical engineer. After serving in World War I, he joined the American Sheet and Tin Plate Company at Farrell, Pennsylvania, and later was transferred as assistant superintendent of strip mills to the company's plant at Gary. After leaving the company in 1931, he was engaged with the installation and operation of the wide strip mills of the Inland Steel Company and Youngstown Sheet and Tube Company. In 1936 he joined the Granite City Steel Company, Granite City, Illinois, as superintendent of the hot and cold strip mills and was promoted in 1937 to general superintendent of plants. In 1942 he transferred to the Carnegie-Illinois Steel Corporation, being stationed at the general offices in Pittsburgh until his appointment in 1943 as assistant to general superintendent of South Works at Chicago, Illinois.

F. C. SCHOEN
DIRECTOR

L. R. MILBURN
DIRECTOR

P. J. BOWRON
DIRECTOR

J. H. VOHR
DIRECTOR

National Committees for 1945

ASSOCIATION OF IRON AND STEEL ENGINEERS

General Chairman, J. L. Miller

ADVISORY COMMITTEE

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1909 JOHN C. REED, *Electrical Superintendent*, Bethlehem Steel Company, Steelton, Pennsylvania.

1910 F. P. TOWNSEND, *Development Engineer*, Copperweld Steel Company, Glassport, Pennsylvania.

1911 L. R. PALMER, National Safety Council, New York, New York.

1914 E. FRIEDLANDER (Retired), Los Angeles, California.

1917 F. D. EGAN (Retired), Buffalo, New York.

1919 D. M. PETTY, *President*, Philadelphia, Bethlehem and New England Railroad Company, Bethlehem, Pennsylvania.

1921 E. S. JEFFRIES, *General Manager*, Universal Boring Machine Company, Hudson, Massachusetts.

1922 W. S. HALL, *Chief Engineer*, Chicago District, Carnegie-Illinois Steel Corporation, Chicago, Illinois.

1923 R. B. GERHARDT, *Chief Engineer of Construction*, Bethlehem Steel Company, Bethlehem, Pennsylvania.

1924 R. S. SHOEMAKER, *Lubrication Engineer*, American Rolling Mill Company, Middletown, Ohio.

1925 A. C. CUMMINS, *General Superintendent*, Youngstown District, Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

1926 G. H. SCHAEFFER, *Electrical Engineer*, Carpenter Steel Company, Reading, Pennsylvania.

1927 S. S. WALES (Retired), Youngstown, Ohio.

1930 F. W. CRAMER, *Electrical Engineer*, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

1931 *Chairman:* F. O. SCHNURE, *Electrical Superintendent*, Bethlehem Steel Company, Sparrows Point, Maryland.

1932 J. J. BOOTH, *Superintendent of Maintenance*, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.

1933 J. D. DONOVAN, *Superintendent of Construction*, Arthur G. McKee Company, Cleveland, Ohio.

1935 W. H. BURR, *Electrical Superintendent*, Lukens Steel Company, Coatesville, Pennsylvania.

1937 H. G. R. BENNETT, *Engineer*, Hot Rolling Mills, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

1938 L. F. COFFIN, *Superintendent*, Mechanical Department, Bethlehem Steel Company, Sparrows Point, Maryland.

1939 C. CLARKE WALES, Engineering Department, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

1940 J. A. CLAUSS, *Vice President in Charge of Engineering*, Great Lakes Steel Corporation, Ecorse, Detroit, Michigan.

1941 W. A. PERRY, *Superintendent*, Electrical and Power Departments, Inland Steel Company, East Chicago, Indiana.

1943 F. E. FLYNN, *District Manager*, Republic Steel Corporation, Warren, Ohio.

1944 CHAS. L. McGRANAHAN, *Assistant General Superintendent*, Jones and Laughlin Steel Corporation, Pittsburgh Works, Pittsburgh, Pennsylvania.

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C. H. WILLIAMS, *Chief Engineer*, Pittsburgh District, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

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C. E. PRITCHARD, *Lubrication Engineer*, Republic Steel Corporation, Cleveland, Ohio.

H. R. ZIMMERMAN, *Superintendent Power and Fuel*, Carnegie-Illinois Steel Corporation, Gary Sheet and Tin Mill, Gary, Indiana.

ROBERT W. COUCH, *Assistant Superintendent Maintenance*, Bethlehem Steel Company, Saucon Plant, Bethlehem, Pennsylvania.

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C. F. COWLEY, *Lubrication Engineer*, Fiske Brothers Refining Company, Detroit, Michigan.

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J. H. STRASSBURGER, *Chairman*, Mechanical and Welding Division.

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E. E. CALLINAN, *Chairman*, Combustion Engineering Division.

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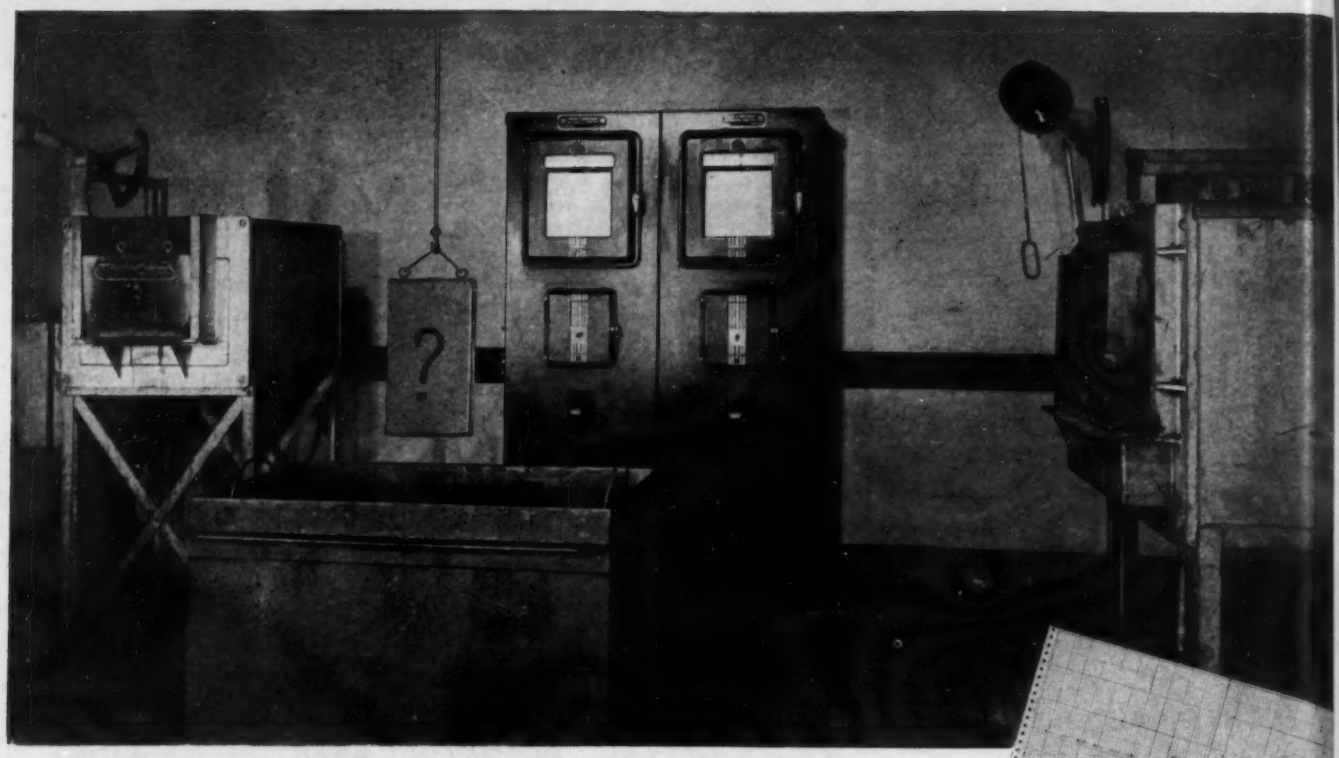
STEVENSON FINDLATER, *Development Engineer,* National Tube Company, Pittsburgh, Pennsylvania.

F. G. KREDEL, *Superintendent, Bar Mills,* Republic Steel Corporation, Cleveland, Ohio.



The experiments being run in this Westinghouse furnace at Heppenstall Co. Pittsburgh, Pa. are secret — but it's no secret that the Micromax Controllers, Duration Adjusting Type, ("D.A.T.") in the background are providing the necessary close control of temperature.

"D.A.T." Gives New Precision For Electrically Heating Almost Anything!

The Heppenstall Co. has for many years used L&N temperature controllers in their laboratories — and when the new type Micromax Recording Controller, Duration Adjusting Type (D.A.T.) was developed, they were quick to investigate it for use on their Westinghouse electric furnaces. They were convinced that this new Controller would give closer regulation than ever before, but they were frankly doubtful that these instruments — or any instruments — could hold the extremely close control which we were inclined to think would result.

But close control is exactly what they're getting — in fact, a glance at the chart at right shows that Heppenstall is now getting *straight line control.* The Micromax D.A.T. Controller accomplishes this because it has a new way of proportioning the amount of heat supplied to the amount required, and its automatic droop corrector, working continuously, corrects temperatures *at* the control point as well as below and above it — in other words, there's no dead spot in this vital control action.

If your heating unit is electric, Micromax D.A.T. Controllers will give you heat-treating precision — rapidly and reliably. For more complete information about this precise method of controlling electric heating units, send for Catalog N-00A(2).

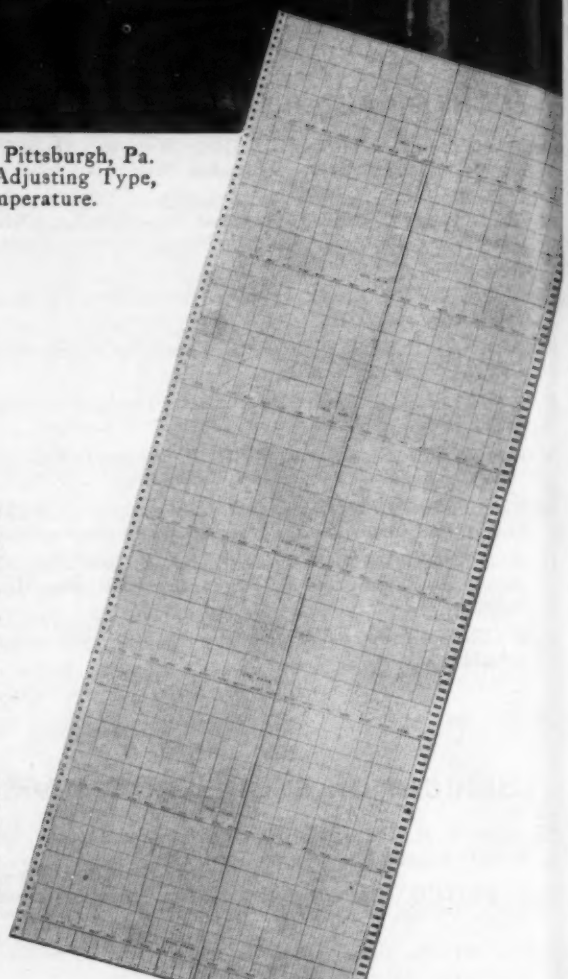


Chart from one of Heppenstall's Micromax D.A.T. Controllers shows the straight-line temperature being maintained.

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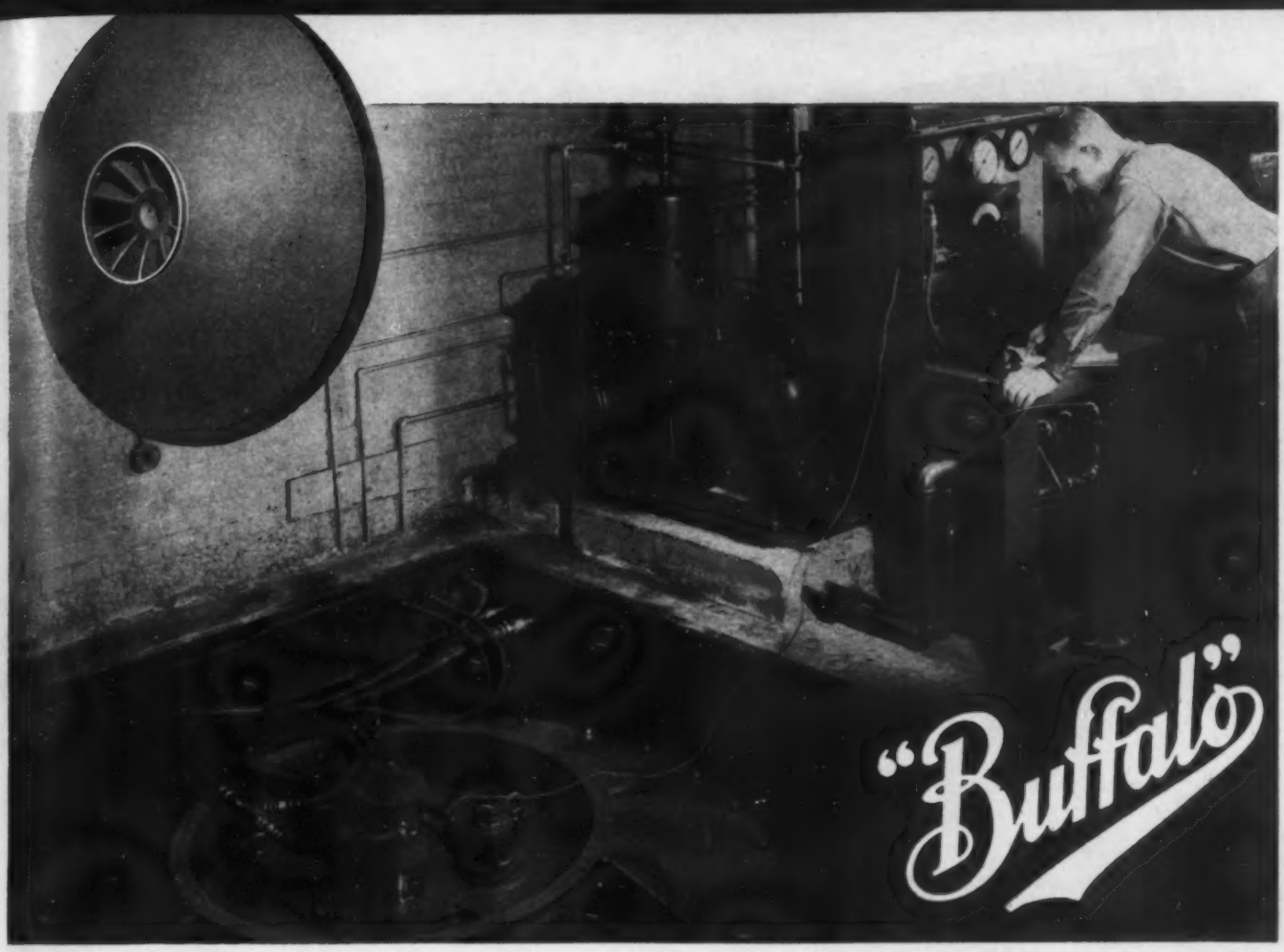

Insert shows new all-welded rotor of high pressure Buffalo Blower. Large illustration shows Vacuum Test Pit.

Test Pit Makes New, Hi-Efficiency, Hi-Speed, All-Welded Wheels Possible

The fan is the heart of the system

"Fan Engineering" — the air Engineers Handbook — 740 pages of useful data.

Price $4.00 Postpaid in U. S. A.

For many years, fan manufacturers have been limited by the unknown speeds at which fan rotors will fail. Because high speed fans are not ordinarily sold in quantity, cost of testing single rotors has been prohibitive. For example, to test a 36 inch rotor at 2000 rpm requires 50 hp, at, say, 4000 rpm, the horsepower mounts to 400. Step this speed up to 8000 rpm and 3200 hp is required. Larger wheels, of course, run proportionately higher.

Because of this, fan manufacturers have in the past wisely kept speeds well below the theoretical limits, so that wheel failures have been infrequent. Sometimes maximum efficiency has been sacrificed because of this fact.

"Buffalo" engineers dissatisfied with this method of design, built the vacuum test pit where rotors are tested to destruction in an almost perfect vacuum. Because there is no air resistance, rotors may be operated at speeds up to 60,000 rpm. In the pit, horsepower requirements, exclusive of bearing friction, are only 1/4000th of that required in the atmosphere.

As a result of experiments "in the pit" Buffalo now offers new high pressure blowers and higher pressure centrifugal compressors. These have newly designed rotors some of which are all-welded. Efficiencies are high — maintenance costs are nil, and the user can be sure of fine performance on the job.

Your requirements may never call for high pressure fans, but when you buy even a disk fan, it's nice to know that the manufacturer is leading the field in the search for better products.

"Buffalo" engineering sales representatives located in all principal cities will be glad to give you full information about Buffalo fans and air conditioning equipment — call them.

"Buffalo" "First For Fans"

BUFFALO FORGE COMPANY

173 MORTIMOR STREET BUFFALO, N. Y.

Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

Buy WAR BONDS

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...regardless of unit size!

4 TIMES LONGER LIFE

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In products and applications... from a wrench to a railroad ... records show that a little Nickel goes a long way to lengthen product life, to reduce bulk and deadweight, and to save maintenance costs.

When compared with costs involved, metals to which Nickel is added invariably rise sharply in service value... due to improved performance.

Nickel imparts strength, hardness, toughness, resistance to corrosion, heat and abrasive wear. In all fields of industry Nickel offers significant advantages. Send us details of your problem for our recommendations.

THE INTERNATIONAL NICKEL COMPANY, INC.

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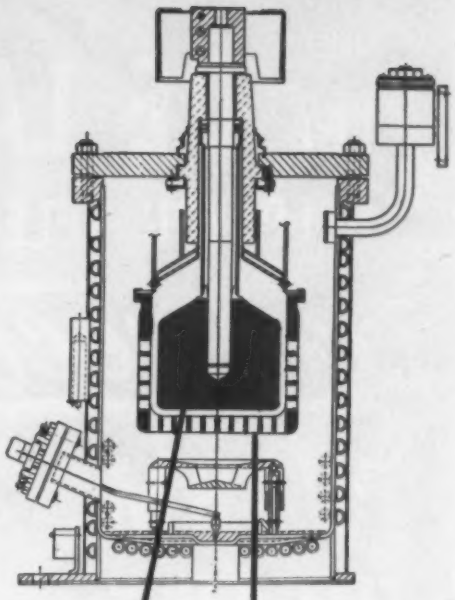
"Unless you can express it as a *Number* you have no information"



THAT'S AN UNWRITTEN LAW in many laboratories today. Because "National" graphite's purity—99.979%—could be expressed as a number, the manufacturer's engineers knew what its performance characteristics would be when used as the anode and anode shield material in this Ignitron Rectifier.

Across the nation, banks of these rectifiers are serving war plants, traction companies, shipyards and mills efficiently and dependably.

Engineers have long known that graphite does not fuse, soften or warp, and has nearly perfect heat radiation properties. Thus, in many types of both vacuum and gas-filled industrial and radio tubes where great heat must be dissipated, or where warpage of multiple tube components must be prevented, graphite is the ideal material.

As pioneers in the carbon and graphite manufacturing business in America, National Carbon Company has brought to highest perfection the art of making high-purity graphite. That is why "National" High-Purity Graphite is most frequently specified for vital industrial and radio tube components. Graphite of even higher purity is supplied for some applications. We welcome the opportunity to discuss the advantages of this "National" electronic graphite.

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Unit of Union Carbide and Carbon Corporation

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The registered trade-mark "National" distinguishes products of National Carbon Company, Inc.

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Too large a worm gear is unnecessarily expensive; too small a gear invites failure. Correct selection depends not only upon transmitted horsepower and ratio of reduction but also upon continuity of operation, shock and other load characteristics. The recommendations of the De Laval representative assure you of the right drive at the right price. He is backed by Home Office engineering experience, gained in furnishing worm gear drives for all classes of service over the last twenty years.

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Help make it *easy*

Whether veterans return to jobs or unemployment, whether post-war buyers spend or hoard their hundred billion dollars now in banks and bonds, whether America's transition to a peacetime economy will be smooth or chaotic, *depends* to a large extent on what *you* do *now*.

War production must come first, but many will have died in vain if victory finds us unprepared for peace . . . Every business executive must recognize the importance of his individual part in the planned program of reconversion.

HERE'S THE IDEA . . . (1) Make an immediate analysis of your reasonable needs to begin post-war business. (2) Place unrated orders for this material to be delivered as soon as restrictions permit. (3) Advise your customers to do the same. (4) Keep up-to-date on W.P.B. and O.P.A. rulings.

HERE'S HOW IT WORKS . . . Unrated orders placed *now* permit suppliers to anticipate your needs and begin production on them as soon as the W.P.B. lifts the bars. This assures *you* of a quicker return to civilian business and customers' orders placed *with* you provide a back-log to start you off when Uncle Sam ceases to be the big buyer.

With all business following this plan America will be ready to capture and hold a gigantic world market. The money to prime the pump of business is here—17 billions of foreign dollars in gold and credits as well as our own piled up savings with which to satisfy a four-year accumulation of civilian needs. This plan will provide jobs for G. I. Joe. Your job is to work the plan.

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Your personal war effort is important (1) *Push production* (2) *Buy bonds* (3) *Plan for peace*

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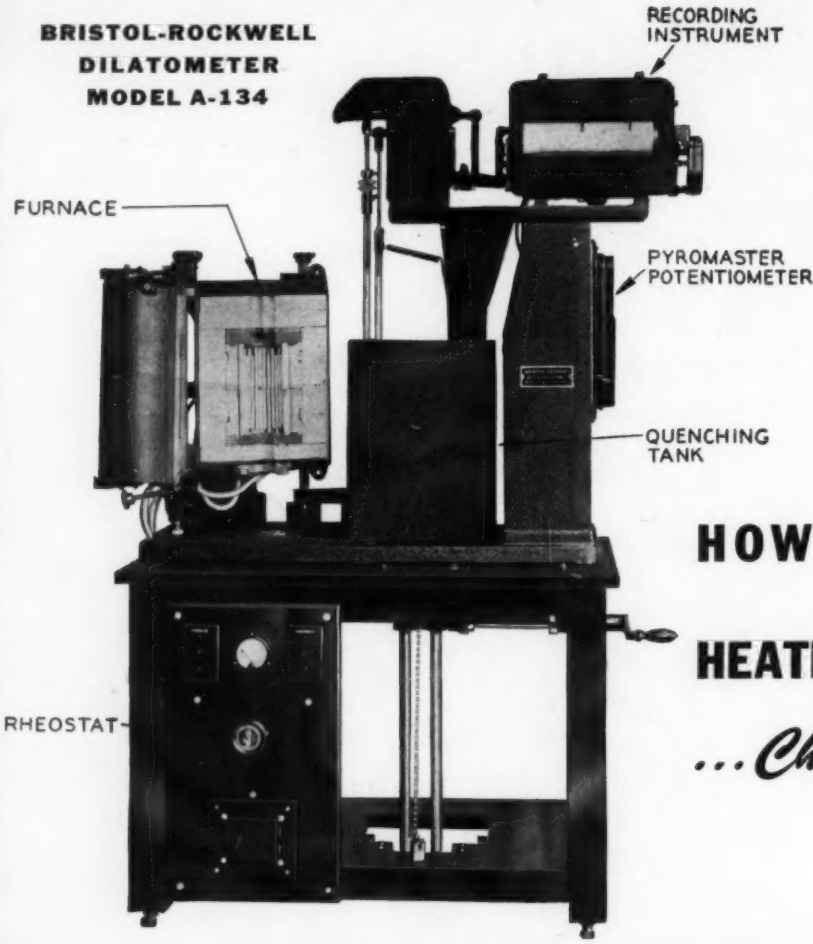

HOW METAL ACTS *when* HEATED AND COOLED

...Charted on Paper

You can get four important types of information about temperature effects on metal—easily and accurately—from the improved model of the Bristol-Rockwell Dilatometer:

- **Critical points of carbon steel**
- **Coefficients of expansion**
- **Composition (from thermal curves)**
- **Heating rates and heat saturation**

Temperature-dilatation and temperature-time changes are recorded simultaneously during heating and cooling cycles.

The built-in electrical furnace (rheostat-controlled) heats to 2500°F. It takes samples up to 5″ x 1⅝″ (best sample sizes: 2½″ to 3½″ long). Ferrous and non-ferrous metals can be tested.

Quenching Tank

An added feature is the quenching tank which can be raised to the quench position without moving the sample or interfering with the dilatation measuring system.

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How continuously it works is what counts

ILLUSTRATED here is a handling operation essential to supplying a fighter-bomber assembly line. It is the kind of job for which the truck must be continuously on duty throughout every shift.

It is thus the kind of job to which a battery industrial truck is well adapted because of its inherent characteristics. With batteries exchanged two or three times per 24-hour day — a job that is easily done in a minute or two — the truck is continuously supplied with power. While one battery operates the truck, another is charged.

Except to exchange batteries, the truck need not stop work for servicing of its power unit. Its electric-motor drives are inherently simple and trouble-free. No other type of truck has so few wearing parts and the current used for charging its batteries is the lowest-cost power available for truck operation.

Altogether the battery industrial truck is one of the most dependable and economical types of handling equipment — especially when powered by Edison Alkaline Batteries. With steel-cell construction, a solution that is a preservative of steel, and a foolproof electrochemical principle of operation, they are the longest lived, most durable and most trouble-free of all batteries. *Edison Storage Battery Division of Thomas A. Edison, Incorporated, West Orange, New Jersey.*

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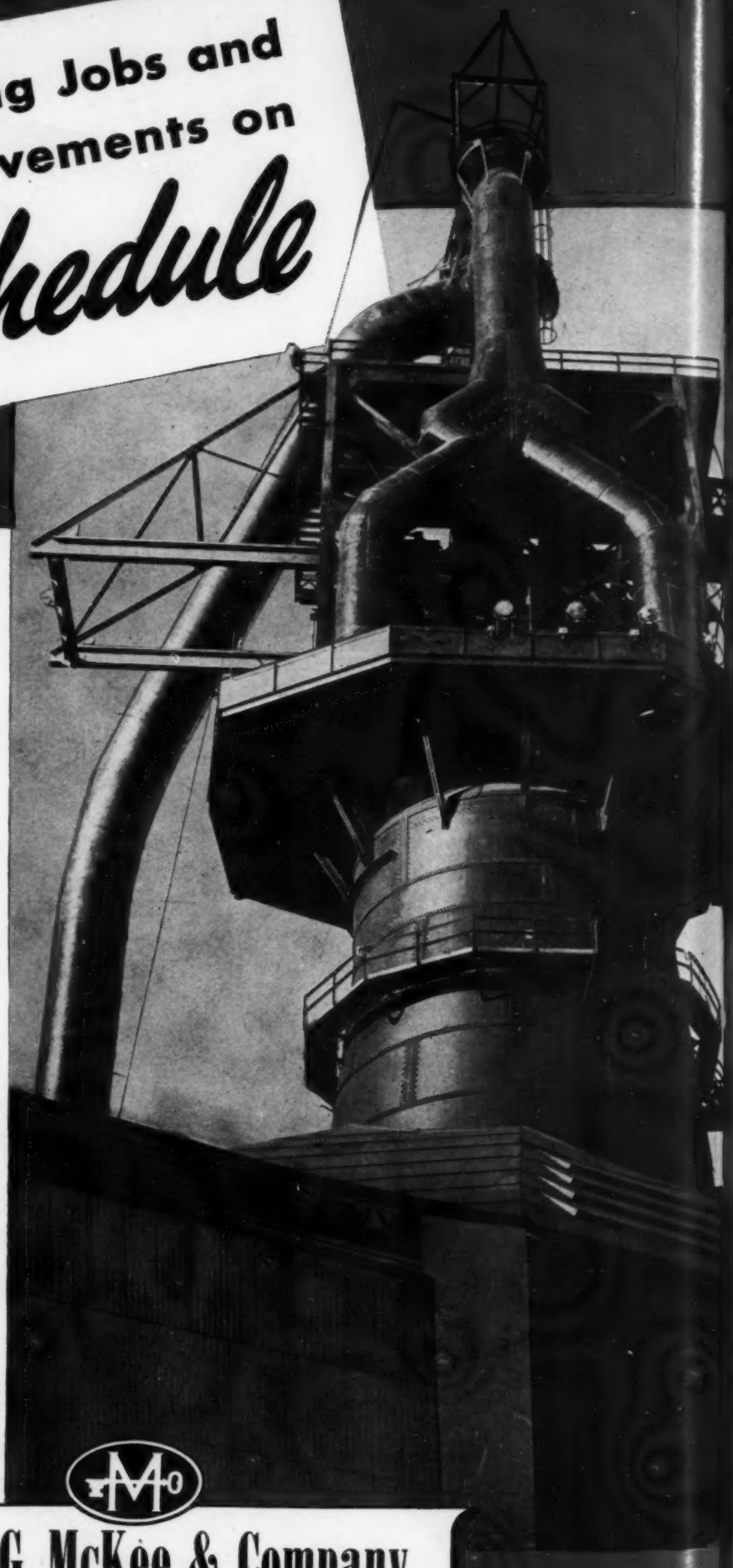
Put your Relining Jobs and Postwar Improvements on *One Schedule*



● Now is the time to plan the future of your plant.

Blast furnaces have been operating at capacity to meet the demand for *maximum* production but the postwar period will bring a demand for *low-cost* production. Alterations or improvements may be necessary to put your plant in condition to meet this demand.

Arthur G. McKee & Company can handle many of your postwar improvements or alterations while your furnaces are being relined.

By making plans *now* for any rehabilitation anticipated during the next five years, work on your plant can be scheduled so that relining and alterations proceed simultaneously.

Consult the McKee organization *before relining* to determine the extent to which your plant efficiency can be increased while relining is in progress.

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★ *Engineers and Contractors* ★

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NEWS SUPPLEMENT January, 1945

Equipment
Personnel
Literature

Iron AND Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

MANUFACTURER ENTERS RUBBER MACHINERY FIELD

▲ The United Engineering and Foundry Company of Pittsburgh, Pennsylvania, one of the leading producers of rolls and rolling mill equipment for the steel and non-ferrous industries, has acquired the Adamson Machine Company of Akron, Ohio, one of the largest producers of machinery for the rubber industry. The consideration was approximately $1,500,000.

The Adamson Company will be reorganized as the Adamson United Company, a wholly owned subsidiary of United. K. C. Gardner, president and general manager of United will become chairman of the board of Adamson United. F. L. Dawes, formerly general manager of Adamson will be president and general manager of Adamson United. Andrew Hale, formerly associated with the Farrel-Birmingham Company will be vice president in charge of sales and engineering. John L. Young, vice president of United will also serve as vice president of Adamson United. George V. Lang, treasurer of United will be secretary and treasurer of the new company. George Fenn, formerly of Adamson will be assistant secretary and treasurer.

The board of directors of Adamson United will be K. C. Gardner, F. C. Biggert, chairman of the Board of United Engineering, F. L. Dawes, Andrew Hale, George V. Lang, John Quinn, manager of United's Canton Ohio plant, and Harry M. Naugle of Canton, Ohio.

KOPPERS COMPLETES 10 BATTERIES IN 1944

▲ Construction of ten batteries of by-product coke ovens, totaling 622 ovens with an annual coal carbonizing capacity of 4,809,000 tons, was completed by Koppers Company, Inc., Engineering and Construction Division in 1944.

During the year the company also started construction of six additional batteries, totaling 457 ovens, with an annual coal carbonizing capacity of 4,027,000 tons.

Firms for whom ovens were completed in 1944, the number of batteries, total ovens and coal carbonizing capacity are: Colorado Fuel and Iron Corporation, Pueblo, Colorado, one battery, 74 ovens, 500,000 tons; Bethlehem Steel Company, Lackawanna, New York, two batteries, 114 ovens, 907,000 tons; Koppers Company, Incorporated, Seaboard Division, Kearny, New Jersey, one battery, 65 ovens, 492,000 tons; Sheffield Steel Company, Houston, Texas, one battery, 47 ovens, 383,000 tons; Lone Star Steel Company, Daingerfield, Texas, one battery, 78 ovens, 633,000 tons; Geneva Steel Company, Geneva, Utah, three batteries, 189 ovens, 1,324,000 tons; Brazilian National Steel Company, Volta Redonda, Rio de Janeiro, Brazil, one battery, 55 ovens, 570,000 tons.

All are Koppers-Becker underjet type ovens with the exception of 114 Koppers-Becker ovens completed for Bethlehem Steel and 140 Koppers ovens started for Carnegie-Illinois at Gary.

Koppers-built ovens now total 11,339 in the United States with a total annual coal carbonizing capacity of 80,877,000 tons, and 397 ovens in Canada with carbonizing capacity of 2,965,000 tons.

MASS PRODUCTION — MANY OUT OF ONE

Twenty torches in unique array, working in unison on an oxygraph at By-Products Steel Corporation, division of Lukens Steel Company, Coatesville, Pennsylvania, speed flame-cutting of steel plates for vital war materiel.

INCREASE EFFICIENCY AND DECREASE OPERATING COSTS

IN the design of "Motor-Rollers", Schloemann engineers have simplified electrical and mechanical requirements to increase efficiency and lower operating costs.

Consider the following advantages of Schloemann "Motor-Rollers":

- FREE ACCESS ALONG BOTH SIDES OF THE TABLE
- MINIMUM NUMBER OF ROTATING PARTS
- LARGE PERCENTAGE OF ROLL SURFACE IN COMPARISON TO OVER-ALL WIDTH OF TABLE
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HYDRAULIC PRESSES • ROLLING MILL MACHINERY

ADDITIVE IMPROVES CYLINDER LUBRICATION

▲ The Hood Refining Company, 195 North Hamilton Avenue, Greensburg, Pennsylvania, are now manufacturing a new lubricant under the trade name of Gibraltar Oil Concentrate. When added to or blended with any good grade of oil in the correct proportion, it produces a super-lubricant according to the manufacturer.

Gibraltar Oil Concentrate is recommended industrially for all types of internal combustion engines such as steam and gas engines, turbines, air compressors, truck engines, vacuum pumps, aviation oils, etc. It thoroughly mixes with any type of lubricating oil, will not settle out or segregate, and cannot be extracted by any filter.

Processed under a secret formula, it prevents formation of hard carbon on valves and rings when used in air compressors and internal combustion engines. It gives better spreading or wetting action to the lubricant treated and actually penetrates the pores of the metal. Cylinder walls become saturated with oil and when the walls heat up, the oil exudes from the pores of the metal, giving instant lubrication. Also because of its wetting ability and heat-resisting properties, Gibraltar Oil Concentrate is recommended to cut the feed of oil on air compressors. It will also definitely reduce the oil consumption in combustion engines. The manufacturer recommends that one part of Gibraltar Oil Concentrate be added to eight parts of regular lubricating oil.

PLASTIC USED IN ACID-PROOF APRON

▲ A new heavy duty acid-proof apron, made with a treated fabric combined with a new plastic by a special calendering process which impregnates the fabric so the product is acid proof throughout is announced by The B. F. Goodrich Company, Akron, Ohio.

The apron is made in one size only, 35 inches by 47 inches, full. It weighs 1¾ pounds complete with sturdy ⅞ inch wide tape, criss-cross shoulder design, attached securely with reinforced grommets at top and side, and with edges hemmed throughout. It can be easily washed or cleaned without harm to its acid-proof qualities.

WIRE BRUSH OFFERS LONG LIFE, FAST CUTTING

▲ A new power brush for removing burrs, preparing metal surfaces, work on rubber parts and many other applications is announced by The Osborn Manufacturing Company, Cleveland, Ohio.

In the applications for which it has been especially designed, the brush has a cutting rate four times as great and a brushing life three times longer than the best fine-wire brushes manufactured up to this time, according to laboratory and field tests concluded by the manufacturer. The new brush, it is said, provides industry with a production tool capable of increasing production rates at a minimum end-of-service cost and extends the application of fine-wire brushes to work hitherto considered impractical.

Designated as the Osborn Monitor Brush No. 1409-S-22, it is a 12-inch monitor section filled with .005-inch Osborn power brush wire and has a 1¼-inch arbor hole. It is especially well suited to aluminum, brass, and other ductile metals for removing burrs effectively without damaging adjacent surfaces of the part, according to the company, and also will find extensive application on hardened and unhardened steel parts. This is because high level, uniform cutting ability is maintained throughout the life of the brush, a quality said to also make the brush suitable for rubber parts and similar applications where there is considerable resistance to the fill-wire.

While possessing the advantages of faster operation, wider application and important operating economies, the new brush also will appeal to operators, the company says, because its fast action reduces fatigue. Operators also will find that with its much faster cutting rate, the action is not harsher, but actually is smoother than the slower cutting brushes.

•

J & L PURCHASES ELECTRIC WELDED TUBE PLANT

▲ H. E. Lewis, president of Jones and Laughlin Steel Corporation, recently announced the purchase from Talon, Inc. of their electric welded tube plant, at Oil City, Pennsylvania.

The plant has facilities for producing electric welded mechanical and pressure tubing in sizes ⅝-inch to 4-inch outside diameter, inclusive. Its products will supplement Jones and Laughlin's present line of seamless, lapwelded and buttwelded tubular products.

The new acquisition will be known as the Electric Weld Tube Division of Jones and Laughlin Steel Corporation and will be operated with present personnel.

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HAYS VISIO-RATIO GAGE

IT SAVES IN MAN POWER because it eliminates the necessity of making calculations to determine air excess or deficiency—does away with lost time in making experimental adjustments.

It saves in fuel because it indicates instantly when there is an incorrect proportioning of air and fuel. It is an infallible guide to highest possible combustion efficiency.

It saves in material through producing greater uniformity in production methods, in minimizing spoilage, etc. It may be used for indicating not only the ratio of air flow to fuel flow—but the ratio between other functions such as pressure, draft, suction, temperature (up to 1000° F) speed in R.P.M. or inches per minute, position, level and others.

The cross-pointer feature is exclusive with the Hays Visio-Ratio Gage. It shows at a glance not only the amount of the two flows but the percentage of excess or deficiency existing between them.

The HAYS CORPORATION
MICHIGAN CITY, INDIANA U.S.A.

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CONTROL OF OPEN
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STORAGE BATTERIES

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THE NEW PHILCO "THIRTY"

Newest of the long series of major storage battery developments pioneered by Philco, is the new Philco "Thirty", the revolutionary battery that gives 30% longer life. Here is the motive power battery for industry's toughest jobs, now and after the war. Write for information. Philco Corporation, Storage Battery Division, Trenton 7, New Jersey.

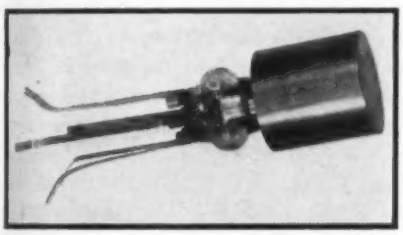
For 50 Years a Leader in Industrial Storage Battery Development

POWER TUBE DESIGNED FOR INDUCTION HEATING

▲ A new compact power tube, first in a series especially designed for industrial use in high-frequency heating equipment, has been developed by the Federal Telephone and Radio Corporation of Newark, New Jersey, manufacturers of a wide variety of vacuum tubes for electronic and communications equipment.

This new tube, designated F-5303, is supplied with 6 in. flexible copper leads permanently secured to the tube terminals. This feature eliminates the glass damage frequently encountered by industrial users in attaching and adjusting terminal clamps on the tube itself, and permits installation and maintenance by inexperienced personnel.

Some of the other outstanding design features of this tube are its unusually sturdy, conservatively spaced filament and grid elements, and an absence of ceramic insulation, both internal and external. These qualities make it ideally suited for use in electronic heating equipment that must withstand the shocks and vibration commonly encountered in manufacturing plant operations.



An oversize filament insures abundant emission throughout the life of the tube, and an extra-heavy anode wall provides large thermal capacity for added protection against momentary overloads.

Rated at 3500 watts input, according to Federal's conservative rating policy, this compact power tube operates at full ratings at frequencies up to 50 megacycles. Maximum ratings are: d-c plate voltage, 3500 volts; d-c plate current, 1.0 ampere; plate dissipation, 1200 watts. The filament current is 27.5 amperes at 11 volts. Overall height of the tube is approximately 7 inches with a maximum diameter of 3½ inches. The F-5303 model is designed for forced-air cooling, but can be supplied for water cooling in model F-5302.

FOUR-STAR PRODUCTION ACHIEVEMENT

The Navy Department recently played a return engagement for the fourth time to award the management and over 700 men and women workers of the Automatic Transportation Company the 4th Silver Star Navy "E" Award for outstanding achievement in the production of electric propelled materials handling equipment required for Navy and Army requirements in the movement of tons of ammunition and vast supplies for the fighting fronts. Captain James C. Byrnes, Jr., USN (Ret.) of the Bureau of Ordnance, presented the award to Elmer F. Twyman, general manager of Automatic.

LIGHT WEIGHT PIPE AIDS INVASIONS

▲ Two plants of the Babcock and Wilcox Company at Alliance, Ohio, have started production on their three thousandth mile of welded invasion tubing used to pipe oil and other necessary fuels to the front, it was announced by officials of the company. The two mills have produced a substantial portion of the country's total output of 4 in. O. D. tubes for invasion pipelines. A single welding unit in one plant produces between ten and twelve miles a day of the tubing, and capacity production is between 20 and 25 miles a day.

The pipe is made in lengths of 20 feet, four inches in diameter, of 14 gage low carbon steel. The thickness is only slightly more than that of an automobile fender. Weighing 67 pounds, the tubes are light enough for a single man to handle, allowing quick action in the field. Three squads of men can lay between 70 to 80 miles miles of tubing a day.

These pipelines have played an important part in the Sicilian, North African, and Normandy invasion campaigns. No longer is the old adage true about an army traveling on its stomach. Today it travels by means of these steel arteries which convey the necessary fluids of mechanized warfare. One petroleum pipeline carries enough fuel to free 250 trucks for other purposes. Unlike a truck convoy, the pipeline makes such a poor bombing target that a 100 lb bomb must strike within a few feet to be effective. One such pipeline requires only one tenth the manpower needed for tanker-truck transport.

REGULATOR COMPANY CHANGES OWNERSHIP

▲ All the stock of the Askania Regulator Company of Chicago, Illinois, makers of hydraulic control systems widely used in the steel industry for automatic control of fuel-air ratio, furnace pressure, etc., has been acquired by General Precision Equipment Corporation of New York. The purchase was made for cash but the exact amount involved was not disclosed. The present management of Askania will continue to be in charge of operations.

RELAY DEVELOPMENTS POINT TO IMPROVED OPERATIONS IN VARIOUS APPLICATIONS

▲ A new relay designed to respond to change in frequency has been developed by Westinghouse. It uses a single electro-magnet and has two balanced circuits arranged so that a small change in power factor makes large changes in current. This results in a high torque for the operating element.

When two parts of a power system, joined by a tie line, are separated by loss of the connecting line, one section may not have sufficient generating capacity to carry its loads. The frequency will begin to fall off, perhaps so rapidly and to such an extent that the two systems cannot be resynchronized until perhaps a great deal of important load has been dumped. To decrease the amount of load dropped and to do it on a preselected basis instead of in the heat of an emergency, is the function of the new relay.

Relays were built for this purpose before, but they have been much more complex, entailing the balancing of two opposing torques (i.e., two electromagnets) on a single disc. The new relay is far superior in being independent of ambient temperature and in the degree of fineness of adjustment.

Another new frequency relay (labeled the CF-1) has other applications. For example, some of the war-born plants such as synthetic rubber factories have surplus electric-power producing capacity. The surplus power is fed into the local system. When, for any reason, the frequency on the public-utility system drops, the relatively small factory generating system tries to shoulder the whole load. The frequency relay enables the tie line to be broken to avoid this impossible condition.

SELECTIVE-POLE TRIPPING

Another relay development, bearing on the problem of holding together systems with single tie lines, is that of selective-pole tripping. This is really an important extension of an idea developed a few years ago, known as single-pole reclosing. Most faults (about 80 per cent) on single-circuit lines are single line to ground. The single-pole reclosing idea, which has proved very successful, is to open and then reclose just that one line instead of all three. This allows the arc to go out, but holds the two ends of the system better as to frequency than if they were cut entirely apart. In case of faults involving two or three phases, all phases are opened in the conventional way.

The new scheme carries this idea further, to open two lines if they are involved in two-phase-to-ground faults or line-to-line faults, which comprise most of the remaining types of faults. This leaves one line tying the system together, which, although not so effective as two lines, does greatly reduce the tendency for the two systems to swing apart in speed before reclosure.

This new system has been thoroughly tested in the field and laboratory, and even under the most severe transients, which produce large phase-angle shifts, the relays always select the correct phase or phases to be tripped.

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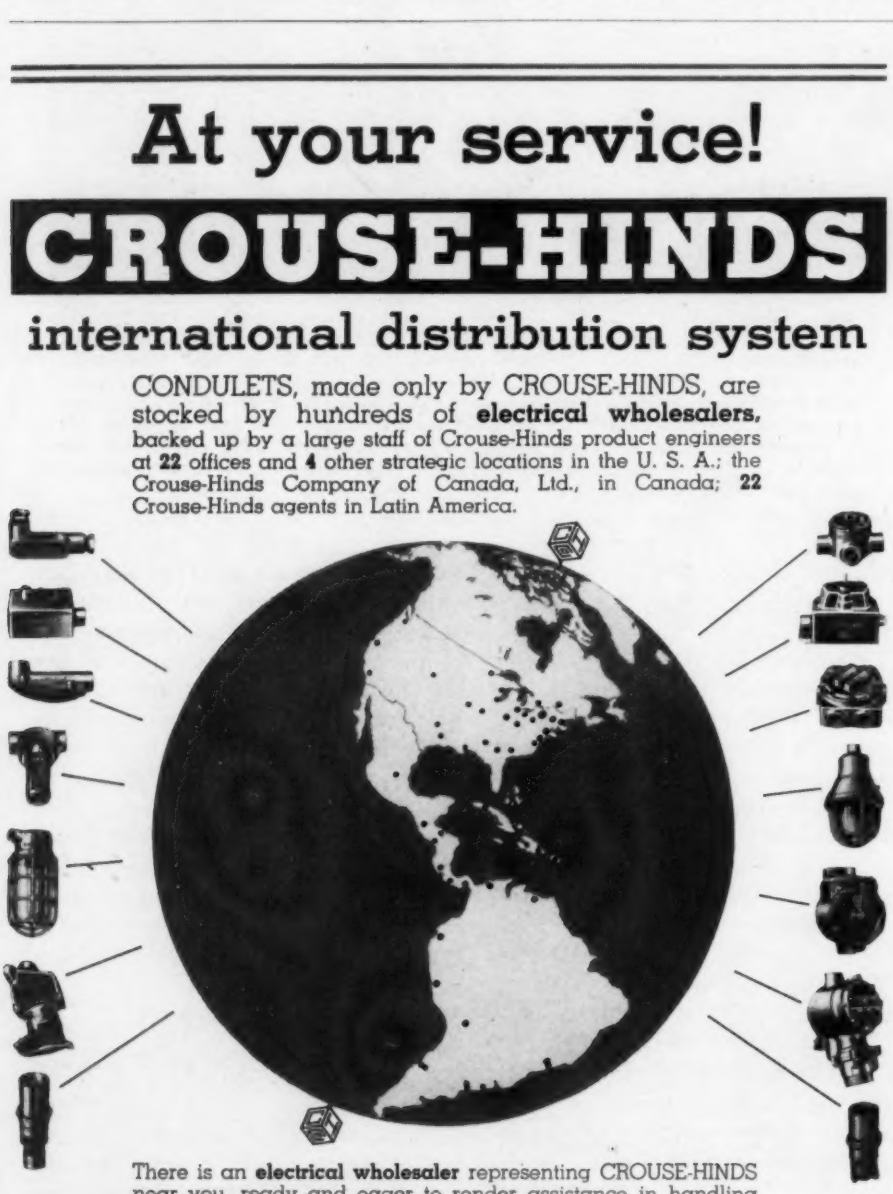

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An improvement on carrier relaying comes about with a relay (HKB) that determines whether a breaker should open or not by comparing the waves at the two ends of a line section. The main features of the new relay method are that it uses one relay for all three phases instead of one for each, and, because it requires no voltage discrimination, no potential transformers are needed. It is also inherently free from interpreting an out-of-step condition as a fault.

CHROMATE GASKETS FIND MANY APPLICATIONS

▲ A new type gasket, consisting of a felt base, impregnated with a chromate pigmented compound which renders the material flame and fire-resistant as well as corrosion resistant, is announced by The Sherwin-Williams Company. Originally intended as a substitute for low-pressure rubber gaskets required in marine ventilating systems, chromate gasketing has since demonstrated its usefulness in many other applications, including joint seals in water, fuel oil and diesel oil systems as well as gasketing for air lock and refrigerator doors.

Chromate gasketing is flame and fire resistant to a high degree, thereby rendering it valuable where inflammable materials must be avoided. It can withstand relatively prolonged exposure to salt water without decomposition. It may be had either factory pre-cut or cut from sheet at the point of use without special tools.

Chromate gasketing employs as a base sheet material, a good grade of thoroughly felted, low shoddy content wool felt. The felt base is impregnated with a specially prepared chromate pigmented compound which is non-drying, tack and water insoluble and renders the felt flexible, pressure resistant and flame resistant. Because the compressibility of a chromate gasket depends considerably on the method of treatment, great care is taken with the impregnating operation.

FLANGING PRESS HAS WELDED STEEL FRAME

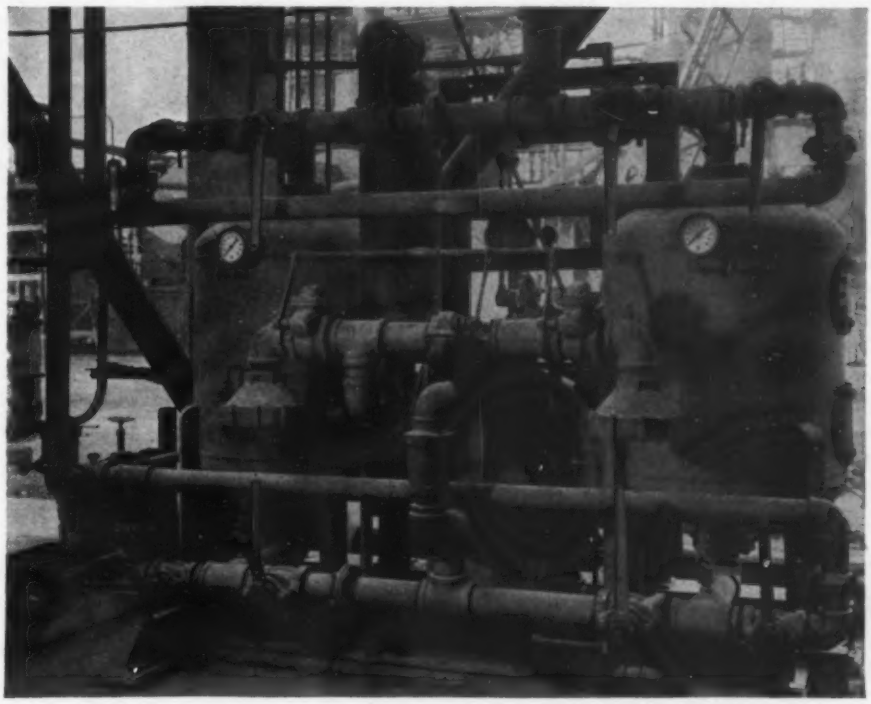
▲ A new 500-ton flanging (joggling) press of the gap type is announced by by the Watson-Stillman Company, Roselle, New Jersey. The new press has a frame of welded steel construction to enable it to handle heavy plate work.

This press has a dual delivery pump (high and low pressure) driven by a 20 hp motor and has a capacity of 103 gpm at low pressure and 14.7 gpm at high pressure. It has an operating pressure up to 2900 psi.

The vertical or main ram has a capacity of 500 tons; stroke, 12 in.; depth of throat, 28 in.; size of moving platen, 36 in. x 36 in.; size of bed, 66 in. x 55 in. The horizontal ram has a capacity of 250 tons; stroke, 7 in.; size of clamping platen, 24 in. x 24 in.

Operating speeds of vertical ram are as follows: advance, 68.5 in. per min; pressing, 9.8 in. per min; return, 106 in. per min. Operating speeds of the horizontal ram are: advance, 135 in. per min; pressing, 19 in. per min; return, 150 in. per min. Separate controls are provided.

This hydraulic press is 14 ft 6½ in. in height and requires a floor space of 5 ft 6 in. x 10 ft 10 in. Its weight is approximatelp 80,000 lb.



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X instruments = 16 men
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That's what happened at a prominent refinery. When the Kemp Instrument Air Dryer pictured above was installed, maintenance troubles were materially reduced. Two men can now handle the number of instruments that formerly required sixteen because of frequent freeze-ups and clogged orifices. In the face of today's labor shortages that is important news!

Of more importance to refinery officials, however, **is the fact that DRY** instrument air insured functional instrumentation and gave them accurate control of processing.

For accurate, trouble-free instrumentation, specify KIA Dryers. In fact, it would pay you to consider drying all your compressed plant air—our engineers will gladly submit recommendations for your study.

Ask For Bulletin 25-C.

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New Literature

▲ Intended for the operating engineer and student interested in the practical side of selecting, operating and maintaining air compressors, "Air Compressors," by Eugene W. Feller covers in complete fashion all types and designs of air compressors. Installation, operation and maintenance information is presented in detail, with emphasis on the practical side rather than on the thermodynamic theories. Published by McGraw-Hill Book Company, 460 pages, $4.50.

▲ "Corrosion," a 54-page publication issued by The International Nickel Company, is a convenient and comprehensive analysis of corrosion principles for both the practical man and the technician in the metal field. It has been prepared in the belief that a good working knowledge of corrosion is the best possible means of securing maximum equipment life and minimum maintenance costs in situations where this destructive process must be taken into consideration.

An opening section explains how corrosion processes work, and discusses all the known factors that influence their action: acidity of solution, oxidizing agents, temperature, agitation, films, inhibitors, surface condition, stress, heat treatment, welding, concentration cells, and galvanic action. These discussions are illustrated with graphs, drawings and tables.

The detailed review of testing methods that follows tells how service conditions are simulated in corrosion research. Included is a description of the construction and use of the well-known spool-type specimen holder for determining the comparative behavior of several metals and alloys simultaneously under actual operating conditions.

The applicability of Monel, nickel and Inconel in various corrosive media is analyzed in the closing section of "Corrosion." Tables list nearly 500 typical corrosives in which these alloys have been successfully used, and report the results of more than 120 specific tests under varied conditions in 44 common corrosive agents.

"Corrosion" will be sent on request to equipment designers, engineers, or other metal users, by The International Nickel Company, Inc., 67 Wall Street, New York 5, New York.

▲ A new bulletin, No. 802, describing the Peabody type M oil burner, has just been prepared by the Peabody Engineering Corporation, 580 Fifth Avenue, New York 19, New York. It describes and illustrates the mechanical and operating features of the burner for natural or forced draft operation and for use with mechanical, wide range mechanical or steam atomizers. Copies may be obtained on request.

▲ A new edition of a booklet on Insulating Fire Brick has been issued by the Armstrong Cork Company, Building Materials Division, Lancaster, Pennsylvania. The booklet, which describes five types of fire brick for temperatures up to 2600 F, features new data on suspended arches and walls and tailor-made arches and domes. Photographs and sketches illustrate the text. Diatomaceous earth and insulating concrete and ingot mold insulation also are described in the booklet.

▲ The how and why of heating furnace control is discussed in a new bulletin, No. 122, published by the Askania Regulator Company. The effects of furnace pressure and atmosphere on economy, quality and scale formation are treated in detail.

Copies may be obtained by writing Askania Regulator Company, 1603 South Michigan Avenue, Chicago 16, Illinois.

▲ The Square D Company, manufacturers of electrical equipment, announces the release of a Fall 1944 edition of the Square D Digest No. 129. This is an abridged catalog containing numerous photographs and listings of products not listed in the previous issue. The Square D line includes safety switches, service equipment, multi-breakers and other circuit breakers, panelboards, bus and feeder duct, motor control and pressure switches.

▲ So that everyone who is in any way concerned with the efficient operation of electrically-heated furnaces, ovens, baths or other units may know of a temperature control system now available for the first time, the Leeds and Northrup Company have just issued a new catalog. It describes a system designed especially to bring to electrically-heated units a regulation of heat-input as dependable as their position-adjusting type of M. E. C. long has brought to fuel-fired furnaces.

This new 25-page publication explains how, by means of an "on-off" contacting system, the heating unit is fed the electric current needed to keep temperature to the required control point or program. Schematic illustrations show the reader how control action is obtained by regulating the proportion of time during which current is "full on" and "full off." Installation photos show the control system in use in representative plants. Also included is an explanation to show how easily an operator can "tune" the control to his particular process.

For a copy of Micromax Electric Control — Duration-Adjusting Type, write for catalog N-00A(2), Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia 44, Pennsylvania.

▲ A new catalog of technical books has just been issued by The Chemical Publishing Company, Inc., 26 Court Street, Brooklyn 2, New York. This catalog includes the latest books on chemistry, technology, physics, general science, mathematics, engineering, foods, formularies, drugs and cosmetics, gardening, medicine, metals, technical dictionaries, etc. This catalog, conforming with the requests of technical and scientific workers and librarians, gives the date of publcation of each book as well as price, number of pages, detailed description and full table of contents. A copy of this catalog will be sent free to everyone who is interested in keeping up with the latest technical and scientific progress.

▲ Roots-Connersville Blower Corporation of Connersville, Indiana, has just issued a new four-page general bulletin, No. G-81-D, covering its rotary positive blowers and gas pumps, centrifugal blowers and exhausters, rotary positive vacuum and liquid pumps, rotary displacement

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Many customers specify Quick-As-Wink valves exclusively because they prefer the Quick-As-Wink design, performance, and construction.

You will find complete information, including sizes, styles, engineering drawings and data in the C. B. Hunt catalog. Write for your copy.

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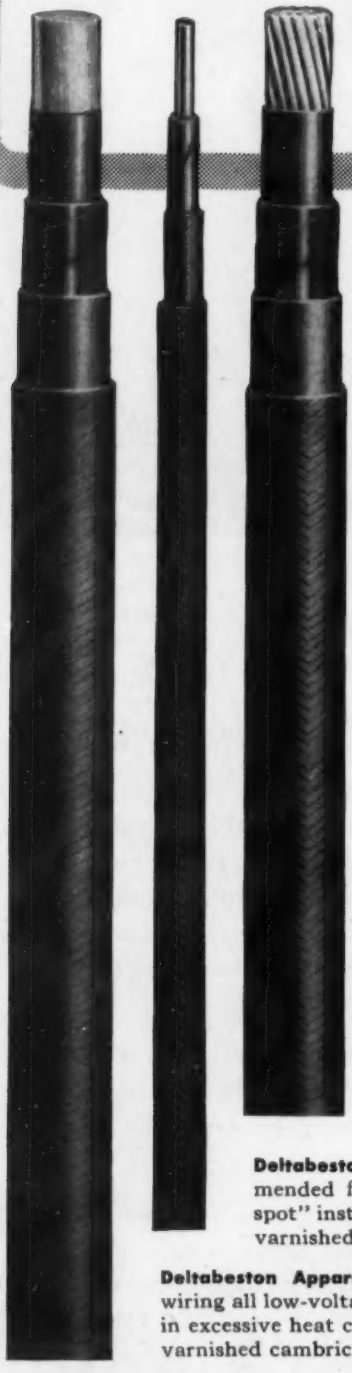
Withstand Constant, Intense Heat



There's no tougher job for power, lighting, and control cables than service in steel mills. Operating conditions here, particularly in boiler rooms, furnaces, soaking pits, kilns, and steam tunnels require a cable with great resistance to constant, intense heat. That's why steel mill operators install Deltabeston Asbestos-insulated Power Cables. These cables have demonstrated time and again that they last and do the job well where other cables soon become unfit for service.

Deltabeston is designed not only to withstand intense heat, but high moisture, oil, grease and most corrosive vapors. Here are only a few of a complete line of Deltabeston Asbestos-insulated Cables. There's a type to fit your exacting requirements.

Deltabeston Power Cables Types AVA or AVL for general power wiring in places where constant high temperatures prevail. Insulated with felted asbestos, varnished cambric insert and asbestos braid or lead sheath over-all.

Deltabeston Boiler Room Wire Type AVA recommended for lighting and control circuits in "hot spot" installations. Insulated with felted asbestos, varnished cambric and asbestos braid.

Deltabeston Apparatus or Motor Lead Wire Type AVA for wiring all low-voltage apparatus where flexibility is required in excessive heat conditions. Insulated with felted asbestos, varnished cambric and asbestos braid—black finish.

For additional information write to Section Y155-31, Appliance and Merchandise Dept., General Electric Co., Bridgeport, Conn. Deltabeston Asbestos-insulated Wires and Cables are distributed nationally by Graybar Electric Co., G-E Supply Corp., and other G-E Distributors.

BUY WAR BONDS AND KEEP THEM

Hear the General Electric radio programs: "The G-E All Girl Orchestra" Sunday 10 P.M. EWT, NBC. "G-E House Party" Mon. through Fri. 4:00 P.M. EWT, CBS.

GENERAL ELECTRIC

gas and liquid meters, and inert gas generators.

This folder is very profusely illustrated. Typical installation views are shown covering the principal applications of Roots-Connersville equipment, such as the chemical and process industries, water works and sewage treatment plants, metal working industries, gas plants and oil refineries, mining and smelting, supercharging and scavenging Diesel engines, and the food and grain industries. The cut legends indicate the range of capacities, running up to 50,000 cfm when handling air or gas, at a maximum of 30 psi.

▲ A new 12-page booklet that describes X-ray diffraction techniques and applications has been announced by North American Philips Company, Inc., 100 East 42nd Street, New York. Diagrams, typical diffraction films, and several tabulations are given in order to show how Norelco X-ray diffraction equipment is used for identification, research and production.

The booklet catalogues many specific problems that can be handled in the following fields: alloys, asbestos, carbon, case hardening, cellulose, cement, cold-rolled steel, dry cells and batteries, electric silicon steel, steel forming, galvanic coatings, greases, ingot iron, patent leather, lime, linseed and china wood oils, oleic acid, paper and parchment, plastic film, precious stones, rayon, resin, resistance alloys, rubber, textiles, tungsten, waxes and waxed papers, wood, cheese, dairy products and soil analysis.

Outstanding features of Norelco X-ray diffraction equipment are clearly explained. Special pages are devoted to powder, back-reflection-focusing, and low-angle scatter cameras. In addition, the booklet describes briefly and simply how X-ray diffraction films can be interpreted.

▲ Cochrane Corporation's reprint No. 36 describes the application and general design of cold water deaerators to prevent corrosion of pipe lines, heat exchange equipment, etc. This type of deaerator will have wide application in industrial plants, utilizing large quantities of cooling water. The reprint on "Water De-

aeration Halts Corrosion of Equipment" is free on application.

▲ In the latest issue of "Handling Materials," house organ of Towmotor Corporation, Cleveland, Ohio, the methods used by stevedores to expedite many varied handling operations are discussed in an illustrated and informative article based on actual on-the-scenes reporting.

The article was prepared after a visit to Jarka Corporation, one of the eastern seaboard's largest stevedores and terminal operators and lists the complexity of handling problems that must be solved efficiently if such an organization is to make a profit. Jarka's solutions to these problems in making stevedoring an "applied science of materials handling," are described in detail.

The Towmotor article was written for readers concerned with handling materials in factories, terminals and warehouses, who are naturally curious about methods employed by those who specialize in handling materials. Copies of the house organ containing the article can be had on request by writing Towmotor Corporation, Cleveland 10, Ohio.

▲ America's newest mechanical revolution, "The Principle of Broaching," has just been graphically presented in the form of a book released by The Lapointe Machine Tool Company of Hudson, Massachusetts, the worlds oldest and largest manufacturers of broaches and broaching machines covering the entire field of broaches and broaching machinery.

This file size, one hundred and eight page book is replete with full color illustrations, engineering diagrams and typical broaching problems and solutions.

▲ A new 8-page folder titled "Some Problems Influencing the Drawing of Fine Wire" by H. P. Edinga, wire division manager, has been announced by North American Philips Company, Inc., 100 East 42nd Street, New York. It is a reprint of a technical paper presented by Mr. Edinga on October 17, 1944 before the annual meeting of the Wire Association at Pittsburgh.

The folder describes the importance of fine wire in the world of today. It discusses drawing problems particularly with respect to the cold-drawn types. Machines, labor, lubrication, diamond dies and production output are a few of the items mentioned in the discussion.

A chart is included in the folder which shows the relationship of die wear to length of wire drawn. The author also tells how output per die has been increased remarkably in the last three years. There is an explanation of the relationship of die production to electrical resistance of the wire. Advantages to be gained by standardization of resistance limits are pointed out.

▲ Available from Ajax Electric Company, Inc., Philadelphia 23, Pennsylvania, is a pamphlet entitled "Salt Bath Quenching Processes." Written by H. J. Babcock, of the Ajax Company and reprinted from Metals and Alloys, it gives much valuable information on isothermal quenching. Copies are available on request.

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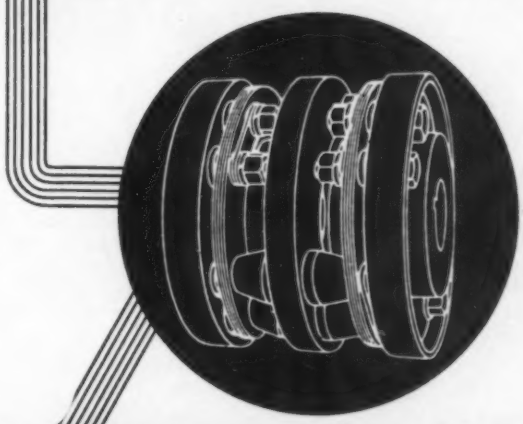
Flexible COUPLINGS



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the four destructive evils of other types and makes of couplings that prevent a permanent care-free installation.

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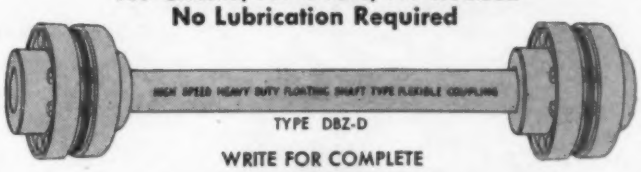

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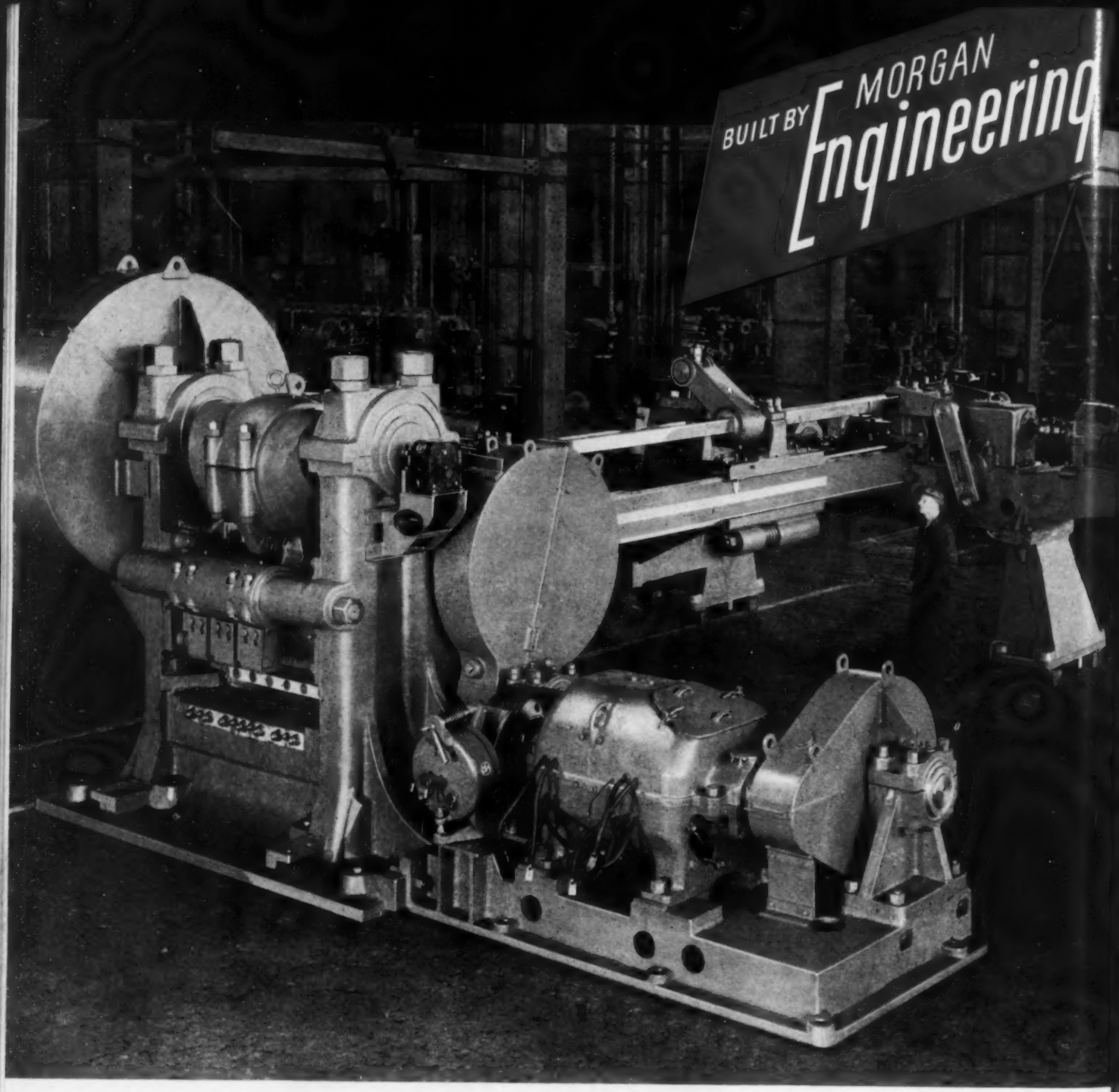

MORGAN 450-TON BLOOM AND SLAB SHEAR

● Among the many types of mill equipment built by Morgan, is the 450-Ton Bloom Shear illustrated above for shearing 12″ x 12″ blooms and equivalent slab sections. Shear is designed without flywheel or clutch for start and stop operation. Hold-down gag is of the independent hand adjusted type. A motor operated gauge is provided for gauging lengths from 2′0″ to 15′0″. Of massive construction, this shear is typical of the types of mill equipment Morgan designs and builds.

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Personnel News

J. Hunter Nead has been named manager of Inland Steel Company's new metallurgical and inspection department, formed by merging the activities of its Indiana Harbor Works metallurgical department, Indiana Harbor Works inspection department, and general office department of inspection and metallurgy. The purpose of this consolidation is to effect a unified control over all of the metallurgical and inspection services of the company and to obtain more complete correlation of these activities. Mr. Nead, who has been with the company for fourteen years, has served as chief metallurgist. His principal office will be at the Indiana Harbor Works. **E. D. Martin** and **T. S. Washburn** will serve as assistant managers. Mr. Martin will be located at the Indiana Harbor Works; Mr. Washburn at the general office at Chicago. **L. S. Marsh,** heretofore manager of the general office department of inspection and metallurgy, will continue in a special metallurgical advisory and consulting capacity. Mr. Marsh has been with the company for twenty-two years.

George W. Whitehead is retiring from his position as assistant general manager of Bethlehem Steel Company's Lackawanna, New York plant. Mr. Whitehead has been associated with the Lackawanna plant since March 1906, when he started as labor foreman. Prior to this he had served for six years with the United States Steel Corporation at South Chicago, Illinois.

Albert H. Shonkwiler, superintendent of the continuous sheet-strip mill at Bethlehem Steel Company, Lackawanna, New York, will succeed Mr. Whitehead as assistant general manager. Mr. Skonkwiler has been with Bethlehem since March 1935, prior to which time he had held positions as strip mill superintendent for Wheeling Steel Company, and general superintendent for Otis Steel Company.

Henry M. Pfahl, formerly with Carnegie-Illinois Steel Corporation as contact metallurgist, is now with Tate-Jones and Company, Inc., Leetsdale, Pennsylvania, as metallurgical engineer and assistant manager of sales.

P. G. McAusland, for the past two years comptroller of the Reliance Electric and Engineering Company, Cleveland, Ohio, has been elected treasurer of the company. He will continue to serve as comptroller. In his enlarged responsibilities, Mr. McAusland succeeds **H. M. Hitchcock,** whose retirement was announced recently.

Mr. McAusland's connection with accounting work dates back to 1925, when he was employed by Scovell-Wellington Company and V. F. Von Rosen and Company, in connection with their work for the Cleveland Railway Company. From 1932 to 1936 he handled accounting for the Street Railway Commission of Cleveland and subsequently became auditor of the Cleveland Railway Company. When the city acquired the transit system in early 1942, McAusland was made chief of the bureau of accounts of the city, the position he relinquished to join Reliance in November 1942.

R. Conrad Cooper has been made assistant vice president, industrial relations, United States Steel Corporation of Delaware. Mr. Cooper was formerly assistant vice president in charge of operations for the Wheeling Steel Corporation. A graduate of the University of Minnesota, where he received a degree of B.S. in civil engineering in 1926, he completed over two years in night school at the Minnesota College of Law. While attending law school he was a field engineer for Universal Atlas Cement Company.

From 1929 to 1937 Mr. Cooper performed industrial engineering work for clients in the textile, stamping and steel industries. He went to the Wheeling Steel Corporation in 1937 as assistant to the vice president in charge of operations and was promoted to his present position in 1940.

J. HUNTER NEAD

P. G. McAUSLAND

R. CONRAD COOPER

Edwin H. Johnson has been appointed to the newly-created position of chief engineer of mines for Republic Steel Corporation. For the past nine years Mr. Johnson has been serving as a mining engineer in the mining sales division of the Jeffrey Manufacturing Company, Columbus, Ohio. He was born in Cannonsville, New York, and attended the College of the City of New York, the Cooper Union Day School of Technical Science and the Carnegie Institute of Technology, receiving his bachelor of science and master of science degree from the latter institution. Upon graduation he spent two years as a coal miner, followed by a year in Fellowship work with the United States Bureau of Mines.

In 1926 Mr. Johnson joined the Coloder Company, Columbus, Ohio, as sales manager and two years later went to the Cardox Corporation in Chicago in the same capacity, later becoming general manager and vice president. Six years later he became a division manager of the Sullivan Machine Company in Michigan City, Indiana, and in 1935 joined the Jeffrey Manufacturing Company.

Mr. Johnson's work will be in connection with both Republic's coal and iron ore mines in the Lake Superior district, northern New York State, western Pennsylvania, Kentucky and Alabama. He will make his headquarters in Cleveland.

Dewey E. Narkates has been appointed assistant to the director of public relations for Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama. Mr. Narkates comes to this position from the engineering and construction department, filling a newly-created position.

Andrew Kaul III has been elected president of the Speer Carbon Company, the International Graphite and Electrode Corporation, and the Speer Resistor Corporation with offices at St. Marys, Pennsylvania.

Thomas F. Dorsey, following a connection of many years with the Fort Pitt Steel Casting Company, for the past ten years as sales manager, is now associated with the Pittsburgh Steel Foundry Corporation, Glassport, Pennsylvania. He was a member of the board of directors of the Steel Founders Society of America during 1943-44, and also served on the executive committee of the society in 1944. Mr. Dorsey will function in a special representative capacity in his new association.

Milton Annich has been appointed superintendent of standards for all nine divisions of American Brake Shoe Company. Mr. Annich rejoined the Brake Shoe organization after nearly two years service with the army in which he was commissioned as a first lieutenant in the combat engineers. He will coordinate standard production and standard costs and assist division operating heads in expanding the standards system.

(*Please turn to page 136*)

HIGH-CALIBRE MEN WANTED

A leading manufacturer of electrical equipment, in business more than a quarter of a century, has several openings in key positions for high-calibre men of the following qualifications: experience in the sale of industrial, railroad and mine-haulage equipment; background of education in electrical engineering; 27 to 35 years of age; potential executive ability.

If you measure up to these requirements, are ambitious, and are looking forward to postwar security and advancement, a letter giving details of your qualifications and experience will be of mutual interest and advantage. All replies confidential. Address Box 365, Iron and Steel Engineer, 1010 Empire Building, Pittsburgh 22, Pennsylvania.

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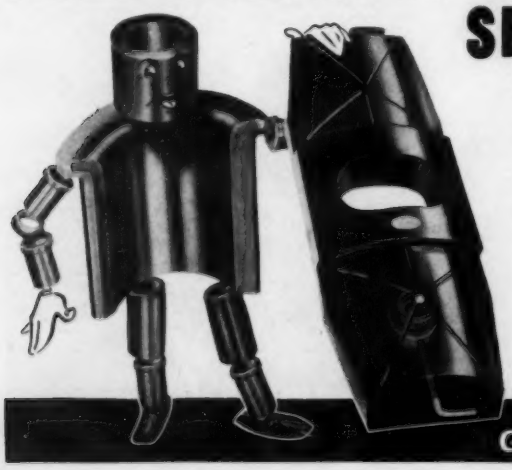

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The GATKE Invention that Revolutionized Universal Coupling Performance . . .

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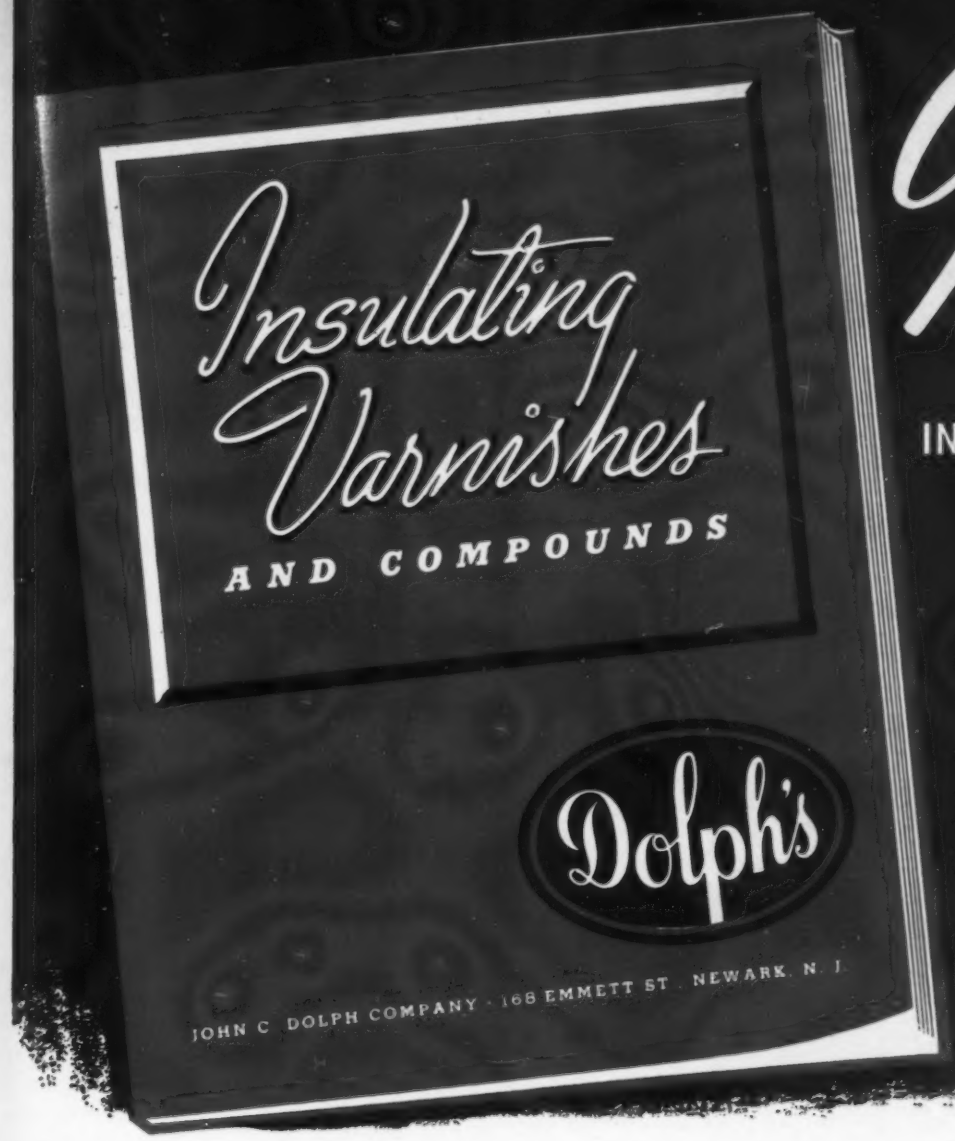

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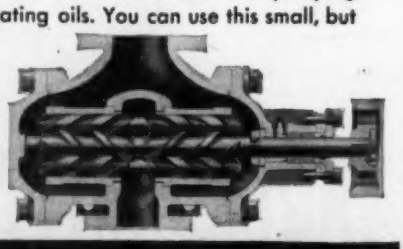

IMO PUMP DIVISION
of the De Laval Steam Turbine Company, Trenton 2, N. J.

Stanley Szacik has been made assistant superintendent of the cold draw department, Allegheny-Ludlum Steel Corporation, Dunkirk, New York, succeeding **Arthur H. Hanks,** recently appointed superintendent. **Anthony Passafaro,** formerly superintendent of hot mills at the Brigham Road plant has been made superintendent of hot rolling mills and hammers at both the Howard Avenue and Brigham Road plants. **Emil H. Forsstrom,** formerly foreman of the finishing department of Brigham Road, has been made assistant superintendent of the Brigham Road plant. **William K. Powers,** formerly night supervisor at Brigham Road, has been appointed assistant superintendent of the hot rolling mills at that plant.

R. A. Williams has been placed in charge of sales for American Car and Foundry Company, succeeding **William L. Stancliffe** who recently resigned from those duties. Mr. Williams was elected a vice-president of a. c. f. in December 1943, and has been Mr. Stancliffe's chief assistant in the sales organization. He has been associated with the company since 1924 when he entered the engineering department at the St. Louis plant.

David C. Prince, vice president of General Electric Company has taken charge of the company's general engineering laboratory, the activities of which will be broadened to include the requirements of the entire company. This change from the responsibilities of application engineering for the Apparatus Department became effective January 1. Mr. Prince has also been chairman of the company's special planning committee.

A graduate of the University of Illinois in 1912, Mr. Prince's service with G. E. has been continuous except for five years beginning in 1914 which he spent with the Illinois Public Utilities Commission and as an officer in World War I. He was for several years associated with Dr. E. F. W. Alexanderson, world famous radio pioneer, was a member of the research laboratory staff and subsequently became research engineer on switchgears and manager of commercial engineering. Mr. Prince is a past president of American Institute of Electrical Engineers.

Obituaries

William T. Schaup, manager of service for Basic Refractories, Incorporated, Cleveland, Ohio, died suddenly on December 3, 1944. Mr. Schaup was born at Pomeroy, Ohio, 1877 and had spent practically his entire life in the steel industry, having started at the age of 14 at the old Homestead Works of the Carnegie-Illinois Steel Corporation. During his career he held many important positions with various steel companies, and was probably one of the best known open hearth men in the industry.

Roy L. Vining, superintendent of the electrical department of the Colorado Fuel and Iron Corporation since 1926, died December 14 after a lingering illness. Mr. Vining was a graduate of Renesselaer Polytechnical Institute. Prior to his association with the Colorado Fuel and Iron Corporation he had been affiliated in the electrical departments of the Singer Sewing Machine Company, Youngstown Sheet and Tube Company at its Indiana Harbor plant and the Detroit Seamless Tube Company.

A. I. S. E.

1945 DISTRICT SECTION MEETINGS

BIRMINGHAM DISTRICT, February 26

"Combustion Control and Its Relation to Smoke Abatement", Barney Schilling, Research Department, Cities Service Company, New York City.

BUFFALO DISTRICT, February 13

"Die Rolling", H. F. Marquardt, Superintendent of Rolling, Republic Steel Corporation, Buffalo, N. Y.

CHICAGO DISTRICT, February 6

"A-c and D-c Motor Protection," by Charles Homer, Superintendent Electrical Department, Youngstown Sheet and Tube Company, East Chicago, Indiana.

"Electronic Controls" by Frank Roberson, Maintenance Division, Gary Steel Works, Carnegie-Illinois Steel Corporation, Gary, Indiana.

"Efficient Handling of Lifting Magnets, Their Maintenance and Repair," by V. E. Holtzlander, Electric Shop Foreman, Inland Steel Company, East Chicago, Indiana.

"Safety Practices," by R. L. Beeswy, Assistant Superintendent, Electric Power Departments, Inland Steel Company, East Chicago, Indiana.

DETROIT DISTRICT, February 13

"Development of the Mechanical Phase of Open Hearth Steel Manufacture," by Folke W. Sundblad, Assistant Open Hearth Superintendent, Great Lakes Steel Corporation, Ecorse, Detroit, Michigan.

PHILADELPHIA DISTRICT, February 3

"Potential Efficiency of Open Hearth Fuels," by B. M. Larsen, Physical Chemist, Research Laboratory, U. S. Steel Corporation, Kearny, New Jersey.

PITTSBURGH DISTRICT, February 12

"The Krause Method of Strip Reduction," by Paul M. Mueller, Chief Engineer in Charge of Development, Blaw-Knox Company, Pittsburgh, Pennsylvania.

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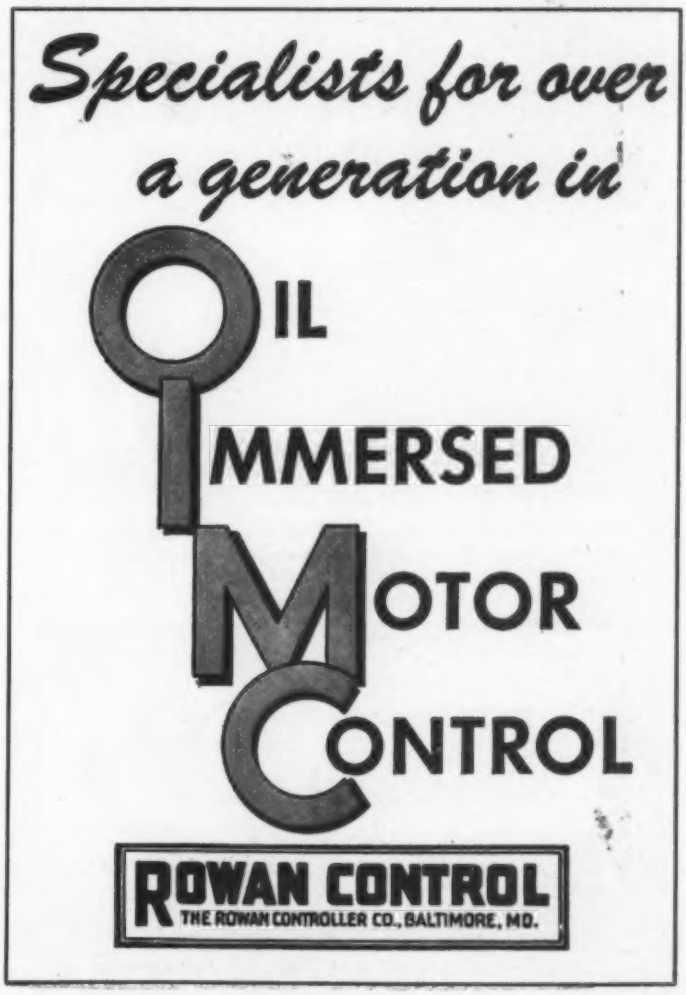


OKOGLASS

...an Okonite "First" for the Navy that will benefit You

IN 1937, when the Navy was searching for greater fire resistance in electrical shipboard cables Okonite research engineers offered a solution in cables insulated with spun glass. Not only were these cables protected with non-combustible glass insulation on the conductors, but even the braid coverings were woven from glass yarn.

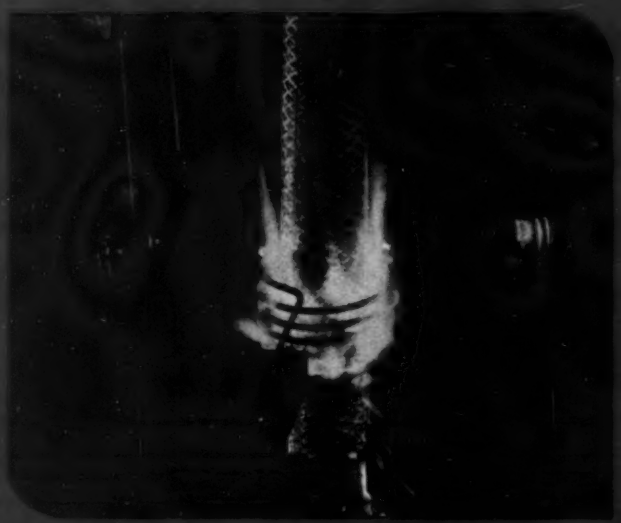
First to submit this construction to the Navy, we had been prepared only because of earlier research on non-combustible network cables for utility undeground systems.

In 1935 such Okoglass cables were approved for hot locations by the Underwriters' Laboratories, Inc. Entirely inorganic — since they contain only copper for conductors, glass for insulation, and a glass braid or lead sheath for a covering — Okoglass cables cannot burn or give off flammable gases.

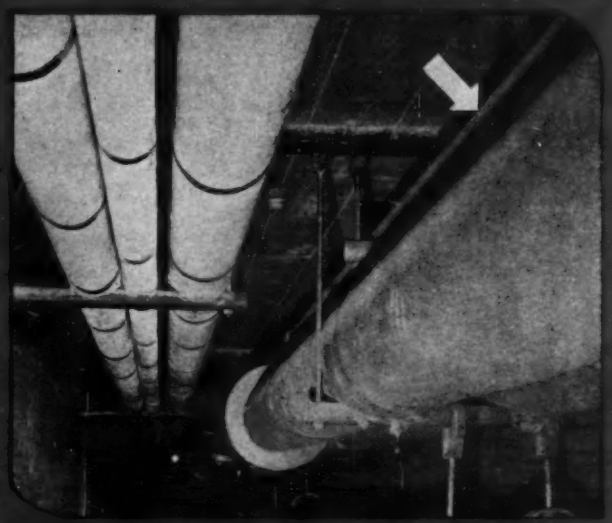
You may have a place where Okoglass insulated cables will eliminate a fire hazard — or outlast other cables that cannot stand high temperatures. Designed in all sizes for operation up to 1000 volts at a temperature of 110°C. (230°F.), Okoglass cables are recommended for use in or near boiler rooms, steam tunnels and furnaces, or in cramped quarters where it is necessary to carry a heavier load on a conductor of limited size. The Okonite Company, Passaic, New Jersey.

OKONITE "FIRSTS" FOR THE NAVY

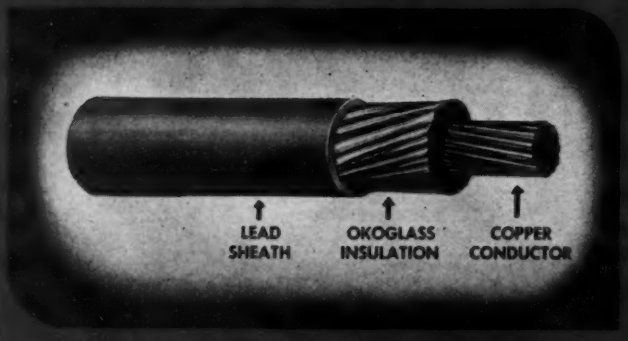
- First to offer a corrosion-resistant lead alloy coating for copper conductors ("Okoloy")
- First to develop a method of assembling conductors to increase resistance against twisting ("Unilay")
- First to supply conductors insulated with a non-flammable synthetic dielectric ("Okoseal")
- First to protect conductors with flame-resistant glass fiber insulation ("Okoglass")
- First to manufacture the synthetic impervious sheath for protecting cables ("Okoseal")



Severe Navy flame tests — and short circuit tests made under operating conditions — demonstrate the non-flammability of Okoglass cables.

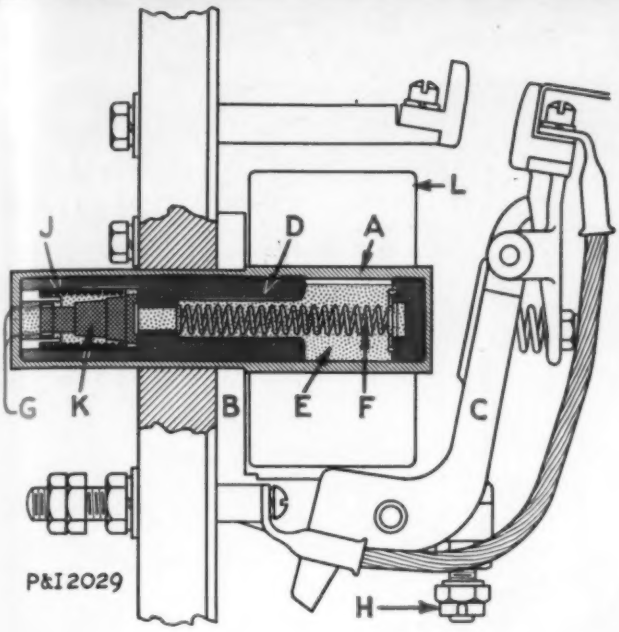


Installed next to a steam line in a tunnel, this Okoglass cable will outlast and carry more current than a similar sized cable with organic insulation.

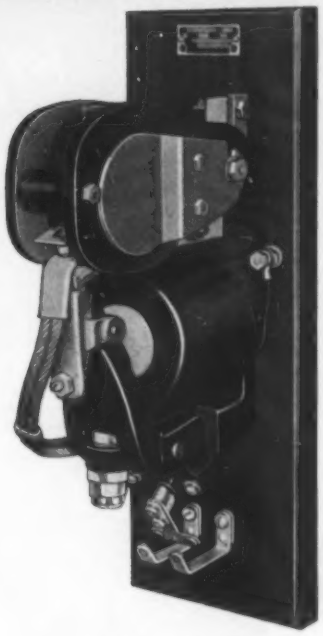


Okoglass cable contains no perishable organic materials.

TO SIMPLIFY WIRING REDUCE NUMBER OF PARTS USE "3C" BULLETIN 7400 VARI-TIME CONTACTORS



Cross Section of Bulletin 7400, Type RT Vari-Time Contactor in de-energized position



Bulletin 7400 Type RT Vari-Time Contactor

"3C" BULLETIN 7400 Vari-Time Contactors with a built-in adjustable Time-Delay, are ideal D.C. motor accelerating Contactors for your heavy duty jobs.

ADVANTAGES

1. You have no separate Time Relays to maintain.
2. Neither does your Vari-Time element need maintenance nor repairs.
3. You have less panel wiring.
4. You need fewer of all repair parts because wearing parts for main and accelerating contactors are duplicates.

OPERATION

See cross section of V. T. contactor in de-energized position. With Coil L energized, a magnetic flux is set up through brass cylinder A, steel frame B, and steel armature C. Since brass core A is non-magnetic, the armature does not close main contacts until steel plunger D is pulled forward into center of coil. Liquid E opposes this motion until it passes through orifice G.

Time delay is provided by this action.

As steel plunger D nears the center of Coil L, the flux builds up, causing armature C to close the main contacts. Steel Plunger D stays at the front of brass cylinder A as long as Coil L is energized.

Armature C immediately drops open when Coil L is de-energized, and Spring F forces steel plunger D back very rapidly.

3 to 1 timing adjustment is providea by adjustable stop H.

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Since April, 1937, the following guarantee has been made: —"The Clark Controller Co. will replace, free of charge, any Vari-Time core which will fail in service during the lifetime of the controller."

You can look to the "3C" design and its many years of successful use for the reliability you demand in your D.C. Contactors for Heavy Duty applications.

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The value of constant "trouble-free" resistor service is magnified by current man-power shortages. Through use of the most durable raw materials and exclusive features of design, P-G Steel Grid Resistors help solve maintenance and production problems. For minimum maintenance and maximum production, use P-G : : : : : : : : : :

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January 1945

Gentlemen:

Since some time has passed in forwarding information at your request regarding the use of our Steam-Vacu-Unit for Open Hearth flue dust removal, we are wondering whether there were any further questions you would care to have answered.

We know that at the time of your inquiry, you were more than casually interested in our product and, surely, with the labor shortage at the present time, no steel producing plant can afford to overlook every possible labor saving device to help our fighting forces to get the necessary badly needed supplies.

Our product is now helping the steel industry to reduce the man hours of Open Hearth flue dust cleanings on an average of 60%, and some of the users reporting a saving as high as 15 hours on elapsed rebuilding time. Representative installations of our equipment are in the following plants:

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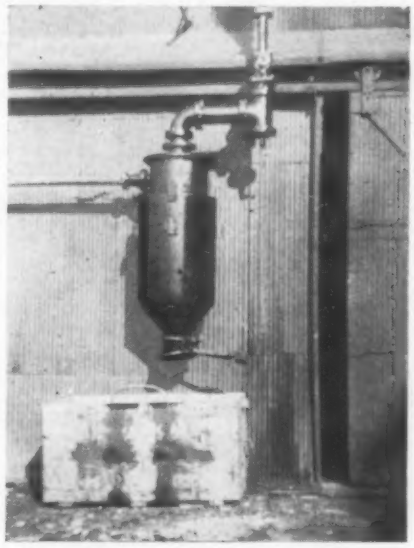

We would be interested in your comments.

Very truly yours

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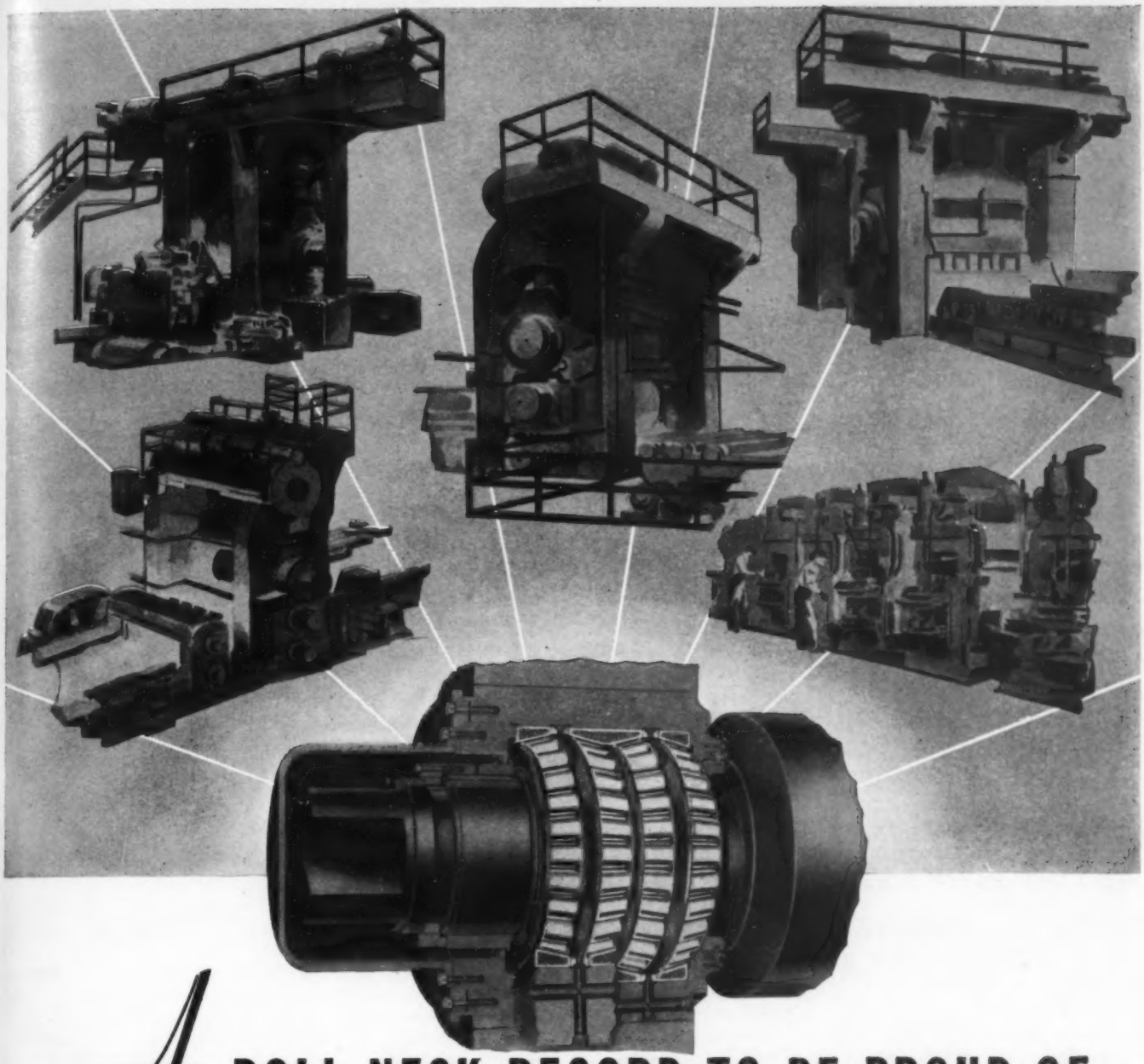
Exide BATTERIES

THE ELECTRIC STORAGE BATTERY COMPANY, Philadelphia 32, Exide Batteries of Canada, Limited, Toronto



A ROLL NECK RECORD TO BE PROUD OF

The performance record of Timken Roll Neck Bearings on mills of all kinds has no parallel; it is a record to be proud of — and we *are* proud of it. Timken Roll Neck Bearings have rolled the highest tonnages ever rolled on high-speed four-high continuous hot strip mills.

They have performed with equal efficiency and economy on two and three high hot and cold reversing mills; bar mills; rod mills; slabbing mills and piercing mills.

But for the pioneering accomplishments of the Timken Roll Neck Bearing it is doubtful whether the high-speed continuous strip mill ever would have been a practical success.

TIMKEN
ROLL NECK BEARINGS

These are facts to be given serious consideration when buying new rolling mills of any kind or remodeling existing mills to meet modern performance standards. The Timken Roller Bearing Company, Canton 6, Ohio.

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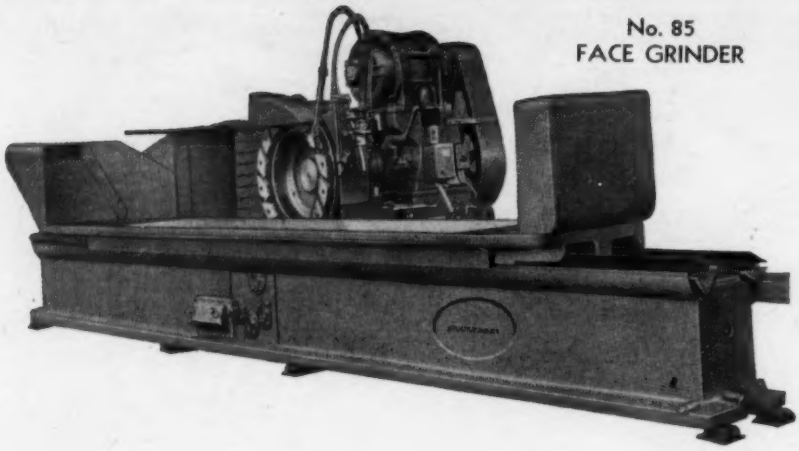

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WET CUT-OFF
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No. 161 HIGH SPEED
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No. 103 VERTICAL
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GRINDER

RECOMMENDED FOR
FAST, ACCURATE METAL REMOVAL
Wherever Accuracy & Production Count!

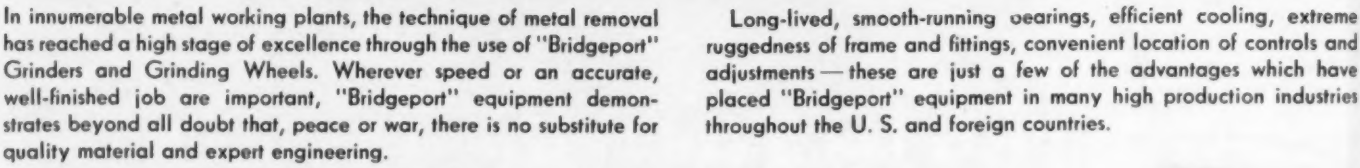
In innumerable metal working plants, the technique of metal removal has reached a high stage of excellence through the use of "Bridgeport" Grinders and Grinding Wheels. Wherever speed or an accurate, well-finished job are important, "Bridgeport" equipment demonstrates beyond all doubt that, peace or war, there is no substitute for quality material and expert engineering.

Long-lived, smooth-running bearings, efficient cooling, extreme ruggedness of frame and fittings, convenient location of controls and adjustments — these are just a few of the advantages which have placed "Bridgeport" equipment in many high production industries throughout the U. S. and foreign countries.

THE BRIDGEPORT SAFETY EMERY WHEEL CO., INC., BRIDGEPORT, CONN., U. S. A.

Bridgeport

GRINDERS • GRINDING WHEELS • BUFFING LATHES



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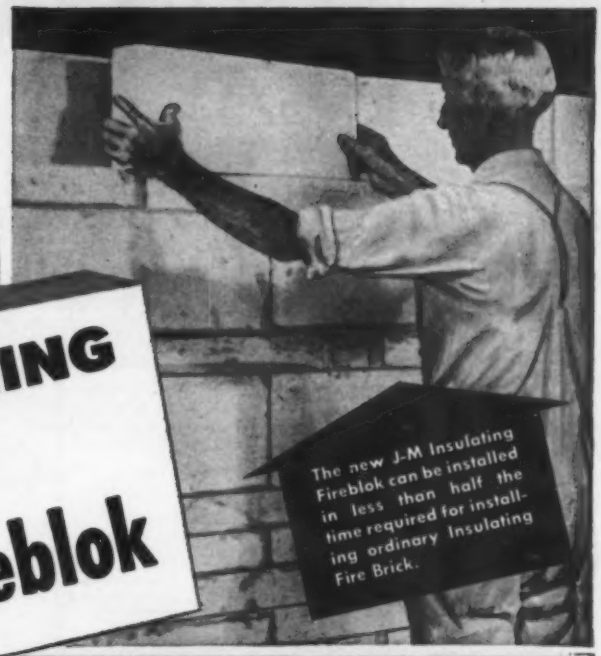
LESS DOWN TIME

FOR FURNACE RELINING with big, new J-M Insulating Fireblok


The new J-M Insulating Fireblok can be installed in less than half the time required for installing ordinary Insulating Fire Brick.

ONE OF THE NEW LIGHTWEIGHT Johns-Manville Insulating Fireblok covers more surface than five Insulating Fire Brick. So, when you reline furnaces with it, you can often get the job finished several times faster. Consider how many hours this can save you in down time, in maintenance crew time . . . and how much faster your furnaces can get back into profitable production.

The larger, more convenient size is the only difference between J-M's four new Insulating Fireblok and the four well-known J-M Insulating Fire Brick. Either size of these four grades of highly efficient refractory linings for use from 1600° F. to 2600° F., has these important advantages:

Easy cutting and fitting—J-M Fireblok can be easily cut with a saw and shaped with a rasp. Most special shapes can be either shop or field cut from standard slabs, reducing the inventory of special shapes.

Minimum of joints—the large size, compared to the standard fire brick unit, materially reduces the number and length of joints, resulting in a thermally more efficient construction.

Economical bonding—with reduced joint length Fireblok requires a minimum of air-set cement for bonding. (J-M 1626 Cement was especially developed for this use.)

Uses—Fireblok can be used wherever Insulating Fire Brick are recommended such as for heat-treating furnaces, flues, stacks, mains and similar equipment. Also for the lining of doors, suspended arches, and, when tapered, for sprung arches of exceptional stability.

Write for new booklet, IN-103A, on this J-M development. Johns-Manville, 22 East 40th St., New York 16, New York.

MOST WIDELY USED BACK-UP INSULATION BETWEEN 600° F. and 1900° F.—J-M SUPEREX

Made of high-quality, calcined diatomaceous silica and bonded with asbestos fiber, Superex combines all the desirable qualities of these two insulating materials. Result: High heat resistance and exceptional insulating efficiency. Ideal for boiler walls, furnaces, etc. Available in 3″, 6″, 9″ and 12″ by 18″ and 36″ blocks. Other lengths to order. Various thicknesses.

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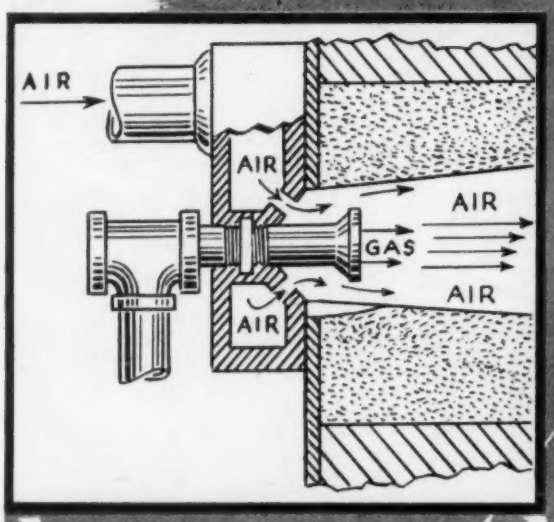
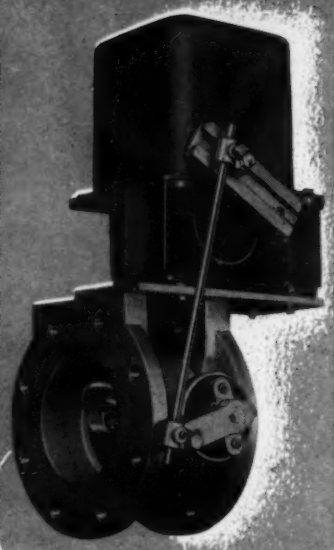
INDUSTRIAL INSULATIONS
FOR EVERY TEMPERATURE . . . FOR EVERY SERVICE

BLOOM

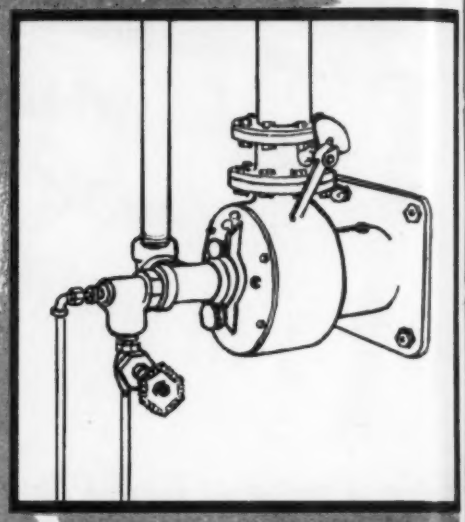
. . . engineers . . . designers and builders of dependable INDUSTRIAL COMBUSTION EQUIPMENT



Tempered-Flame Burners for economical Controlled Heating and Cooling Cycles



Leeds Northrup motor operated, through shaft Gas Butterfly Valves



Long Flame Burner, permits change from gas to oil, oil to gas without shutdowns or delays

Bloom engineers are always glad to analyze your combustion problems and suggest uses for the new developments, and improved methods of heat control. As designers and builders of economical, dependable burners and other combustion equipment, utilizing all types of fuel—Bloom is not committed to any one fuel or method of operation—except that which will do your job best. Technical bulletins are available on all equipment listed below—write today.

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Open Hearths · Metal Mixers · Soaking Pits · Slab and Billet Reheating Furnaces · Annealing Operations · Forge Furnaces · Melting Furnaces · Air Furnaces · Core Ovens · and in every other manufacturing process where controlled heat is vital to successful low cost operations.

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does work of 7 men with hand trucks

—Releasing these men for productive work

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Weights per trip vary from 3,000 to 10,000 lbs., trips vary from 100 to 500 ft. Hundreds of tons of skidded metals are handled in the course of a week by the one truck. Formerly, this work required as many as 7 men with hand trucks. These men have now been released for actual production work—helping to solve the company's manpower problem.

The new Baker Catalog No. 52 describes many case histories showing how Baker Trucks effect similar savings in a wide variety of installations. Call your nearest Baker representative or write for your copy today.

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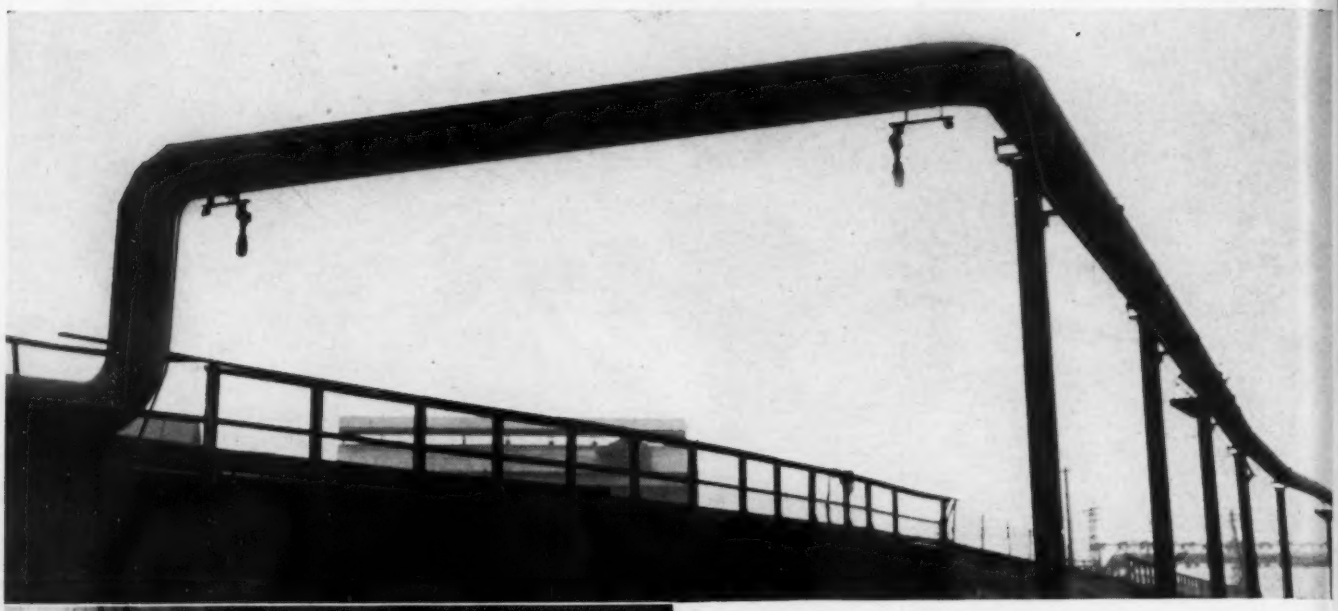
GAS MAIN CLEANING

A Specialty!

PHOTOS BELOW ARE OF A BLAST FURNACE GAS MAIN CLEANED BY

PITTSBURGH PIPE CLEANER SERVICE

(Name of steel company on request.)



DISCHARGE OF DEPOSIT

Length—1130′
Diameter—20″
Seven 90° bends
Ten 22½° bends
One 45° bend

Results — 40% increase in flow; seven tons dirt removed.

Time — 6¼ hours shut-down time required.

Openings — two.

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"Continuous Balance" is a new principle in pyrometry. It makes the Brown *ElectroniK* Potentiometer an outstanding advance in instrumentation — probably the greatest step forward in several decades.

In this advanced potentiometer controller, the "Continuous Balance" unit supplants the galvanometer used in conventional mechanical-type potentiometers employing a periodic or cyclic mechanism.

As an Air-operated Controller it provides the ideal synchronization of measurement and control for temperature processes.

What "Continuous Balance" does for measurement — "Air-o-Line Control" does for fuel modulation, being capable of infinite fineness in fuel valve adjustment.

Used with conventional wiring and thermocouple installations, Brown *ElectroniK* Potentiometers are rapidly outmoding all other forms of temperature controllers in heat treating processes.

Thousands of operating hours have proved the Brown *ElectroniK* Potentiometers' superior performance — sensitivity — and ruggedness.

Write for Catalog 15-4, THE BROWN INSTRUMENT COMPANY, a division of Minneapolis-Honeywell Regulator Company, 4464 Wayne Avenue, Philadelphia 44, Pa. Offices in all principal cities. 119 Peter Street, Toronto, Canada — Wadsworth Road, Perivale, Middlesex, England — Nybrokajen 7, Stockholm, Sweden.

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Annealing
Hardening
High Speed Salt Baths
Lead Baths
Stress Relieving
Sub-zero Treating
Normalizing
Nitriding
Carburizing

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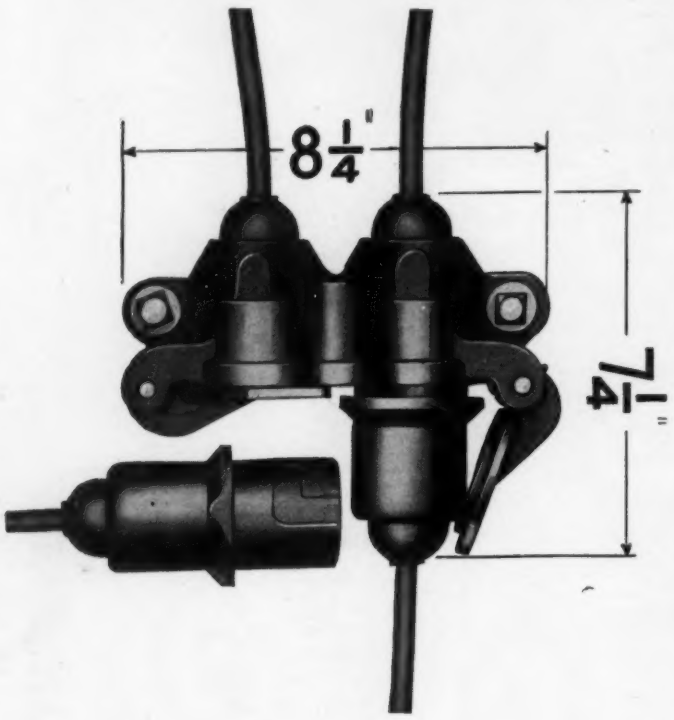
BROWN *ElectroniK* POTENTIOMETERS

OHIO ARMORED
WEATHER PROOF
CONNECTORS



Save time to make or break connections.

They are operated by hand, (see the Bayonet Joint in Cut).

No Tools or Tape required.

No danger, live parts covered by insulated Iron Shell.

Two Pole Connectors have Automatic Spring Cover closing live end when not connected.

They also have support Ears for mounting (see cut).

Single Pole Connectors are furnished without Spring Closing Covers or Support Ears.

Cable Ends are No. 4 B & S Extra Flexible Rubber Insulated Wire.

Capacity 150 amperes continuous.

	Weight	Net Price
Single Pole Connectors	5 Lbs.	$12.00 Each
Double Pole Connectors	13½ Lbs.	$25.00 Each
Lower or Plug End Separately		$ 7.50 Each

Priority required — F. O. B. CLEVELAND

OHIO reliable MAGNETS

The OHIO Electric Mfg. Company
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Protect Gears --Stop Noise! Prolong Life

Steel mill gearing costs a lot of money and its protection requires definite performance from lubricants. Ordinary gear greases and shields don't protect gear teeth, because they cannot resist the effects of speed and pressure.

NON-FLUID OIL protects gear teeth effectively — because it is so adhesive that it keeps gears coated with a continuous film of lubricant — it is not thrown off by speed, or forced out by pressure. Furthermore, NON-FLUID OIL resists heat, so will not thin out and run off. Nor will it "ball up" and roll off gears in cold locations.

NON-FLUID OIL is being used successfully in leading iron and steel mills. Send for instructive bulletin.

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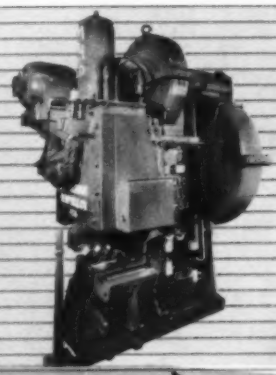
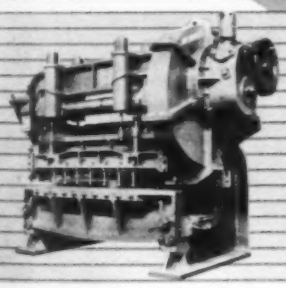
IN U.S. PAT. OFFICE & FOREIGN COUNTRIES

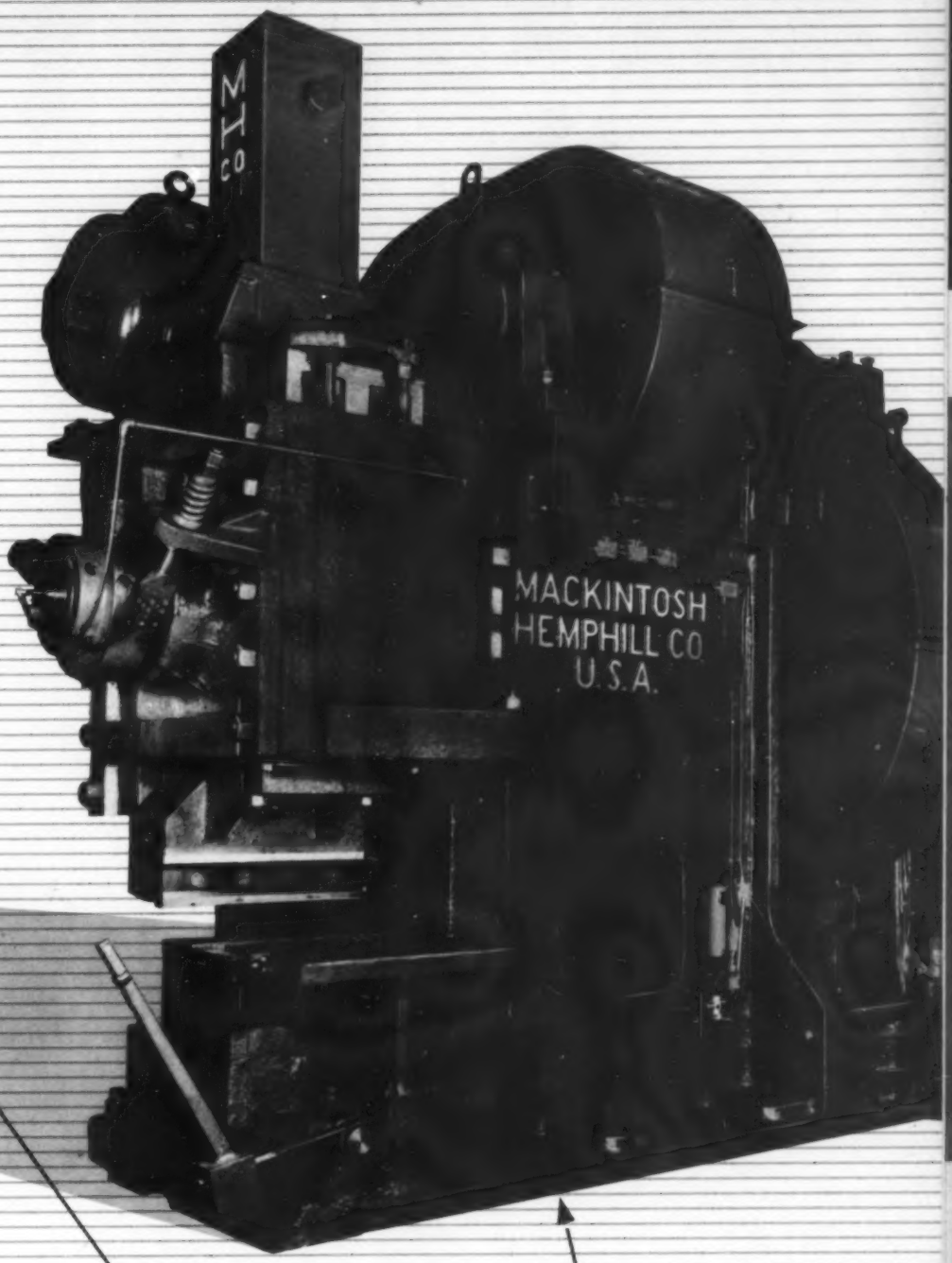
Modern Steel Mill Lubricant

Better Lubrication at Less Cost per Month

Are you set for stiffer competition?







Model B1 Billet, Bar and Shape Shear (2¾" x 2¾" mild cold steel.)

Model B 6-Billet, Bar and Shape Shear (7" x 7" mild cold steel.)

1" thick x 100" wide Plate Shear.

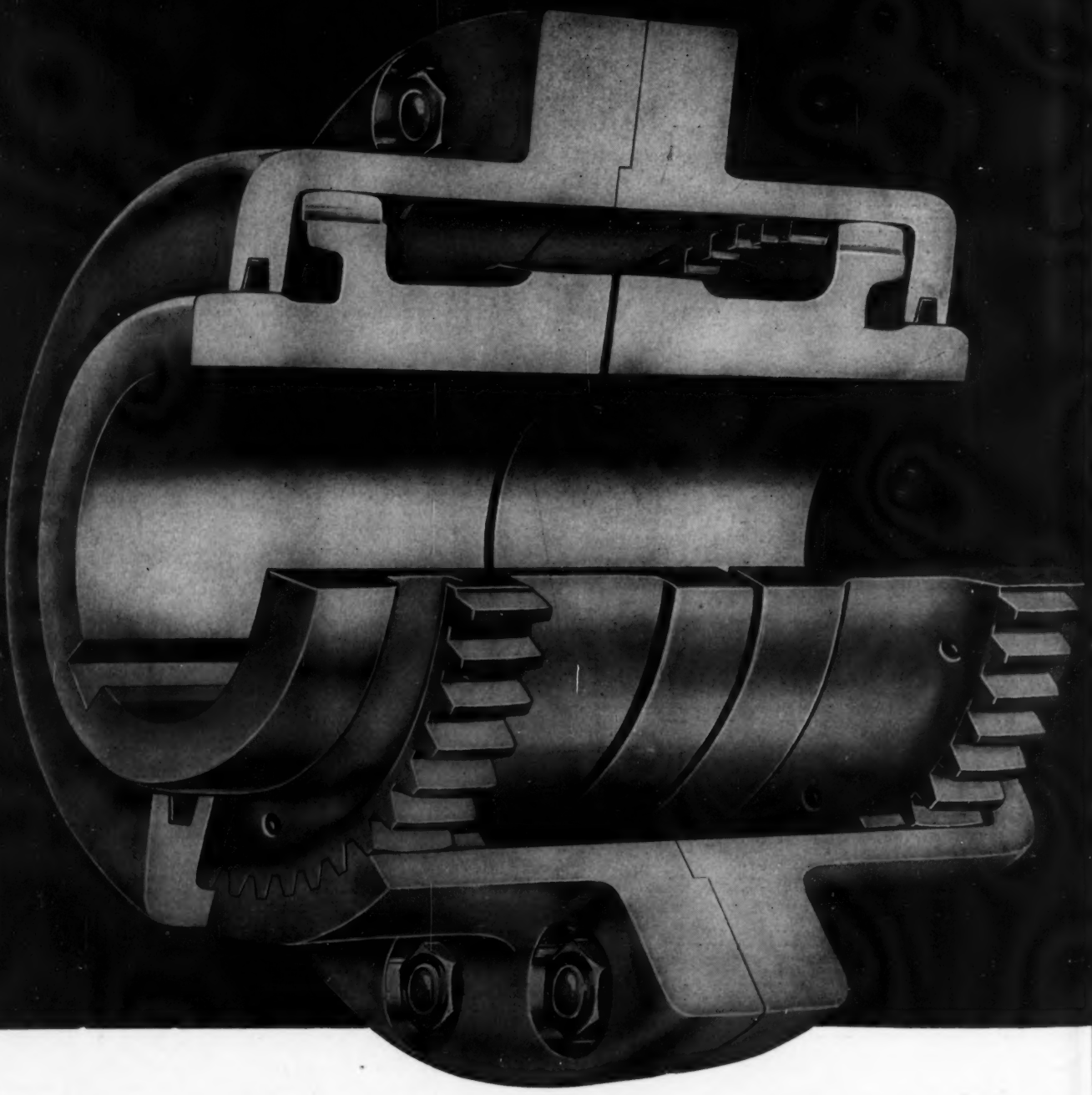
MACKINTOSH-HEMPHILL *modern* shear design means FASTER, CLEANER, MORE ECONOMICAL CUTS

Are your shearing costs too high? Mack-Hemp Shears have cut operating expenses in dozens of plants. They are the last word in economical, large volume production. They typify what M-H advanced engineering and plenty of "know how" manufacturing experience can accomplish. Available in six sizes of billet shears (up to 7" x 7" mild steel billets) and plate shears from ⅜" to 2" thick (up to 156" wide) they give you a definite advantage in meeting today's production schedule and tomorrow's market price . . . Write for details.

MACKINTOSH-HEMPHILL CO., Pittsburgh and Midland, Penna.

Makers of the Rolls with the Red Wabblers

POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST

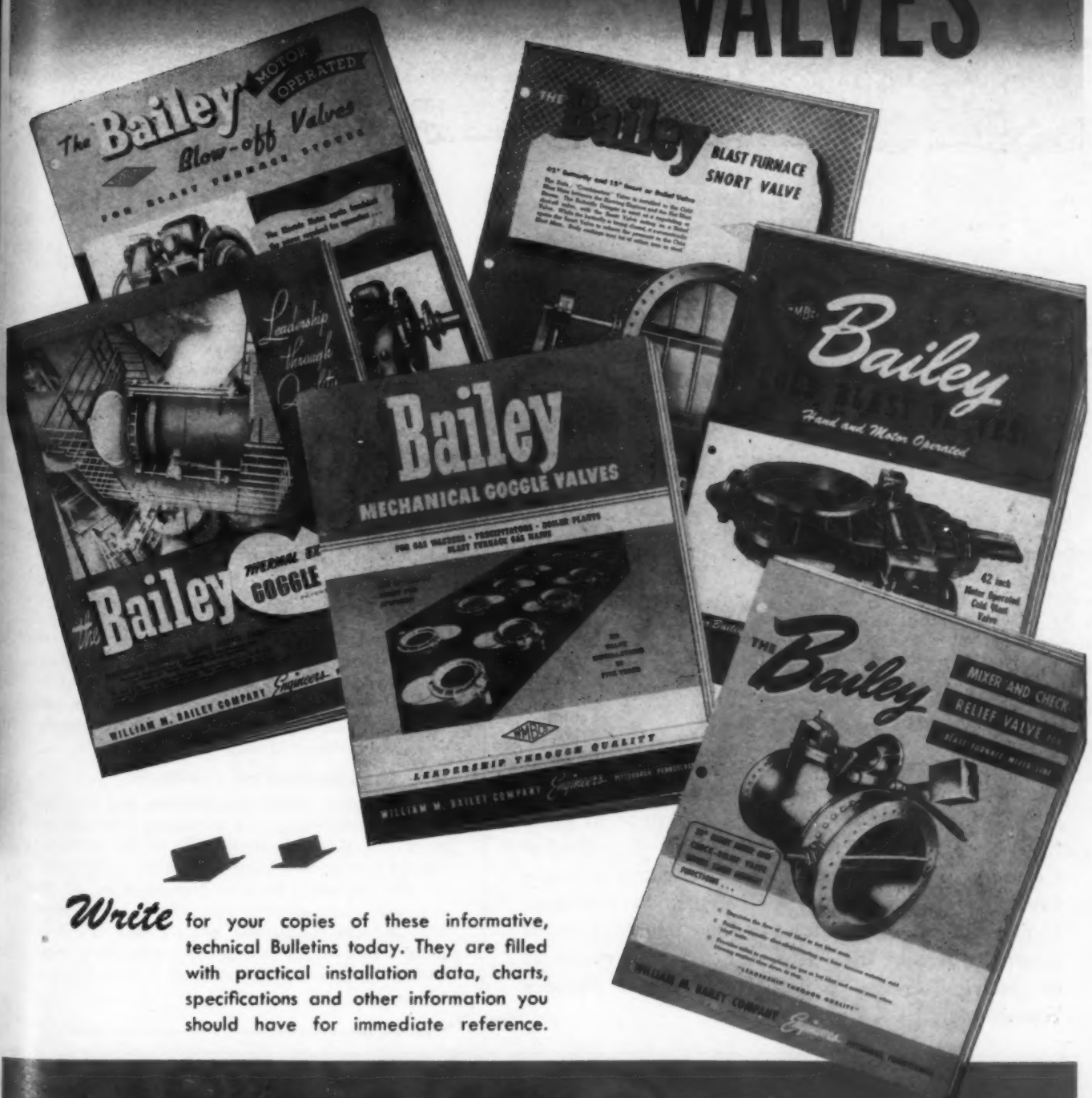
FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY

WOODBERRY, BALTIMORE, MD.

THE Bailey *Precision Engineered*

BLAST FURNACE VALVES



Write for your copies of these informative, technical Bulletins today. They are filled with practical installation data, charts, specifications and other information you should have for immediate reference.

WILLIAM M. BAILEY COMPANY *Engineers* PITTSBURGH, PENNA.

1 MILLION KVA of Pennsylvania Furnace Transformers now in Service!

YES, Pennsylvania Furnace Transformers, totaling 3/4 Million KVA, are supplying power to hundreds of electric furnaces. The successful operation of these transformers has given Pennsylvania Transformer Company a noted reputation in the Furnace Transformer field. For over 30 years, Pennsylvania Engineers have closely followed the development of Electric Furnaces. They fully understand the problems of Electric Furnaces and their relation to Furnace Transformers.

SOME PROBLEMS OF DESIGN AND HOW THEY ARE MET

1. *Overloads.*

Electric Furnace operation inherently subjects Furnace Transformers to heavy overloads. To carry these overloads safely, a low temperature gradient must be maintained between copper and oil. Pennsylvania coils are designed so that a large surface of each wire in the high voltage and low voltage windings is directly exposed to the cooling oil. Large vertical ducts distribute the oil through the coils. Ducts are clear and unobstructed; hot spots cannot develop in the windings.

2. *Balancing of Stresses.*

Pennsylvania coils are balanced to reduce the radial and axial short circuit stresses to a minimum. 1. The circular shape protects the coils against deformation due to radial short circuit forces. 2. The total axial short circuit force is calculated for each design and the coils are subjected to an equivalent pressure in a three hundred ton hydraulic press. The ability of the coils to maintain their shape, under the prescribed pressure, guarantees that the transformer will safely withstand short circuits.

3. *Distribution of Currents.*

Due to heavy secondary currents, the windings must be subdivided into numerous parallel sections. A skillful arrangement of the windings insures that each section carries an equal share of the current. Careful transposition of the individual conductors of each section in the windings reduces the copper eddy losses to a minimum. This results in improved efficiency, more uniform copper temperature and prevention of hot spots.

Pennsylvania
TRANSFORMER COMPANY

Pennsylvania TRANSFORMERS

Furnace Transformer Experts

PITTSBURGH, PENNSYLVANIA

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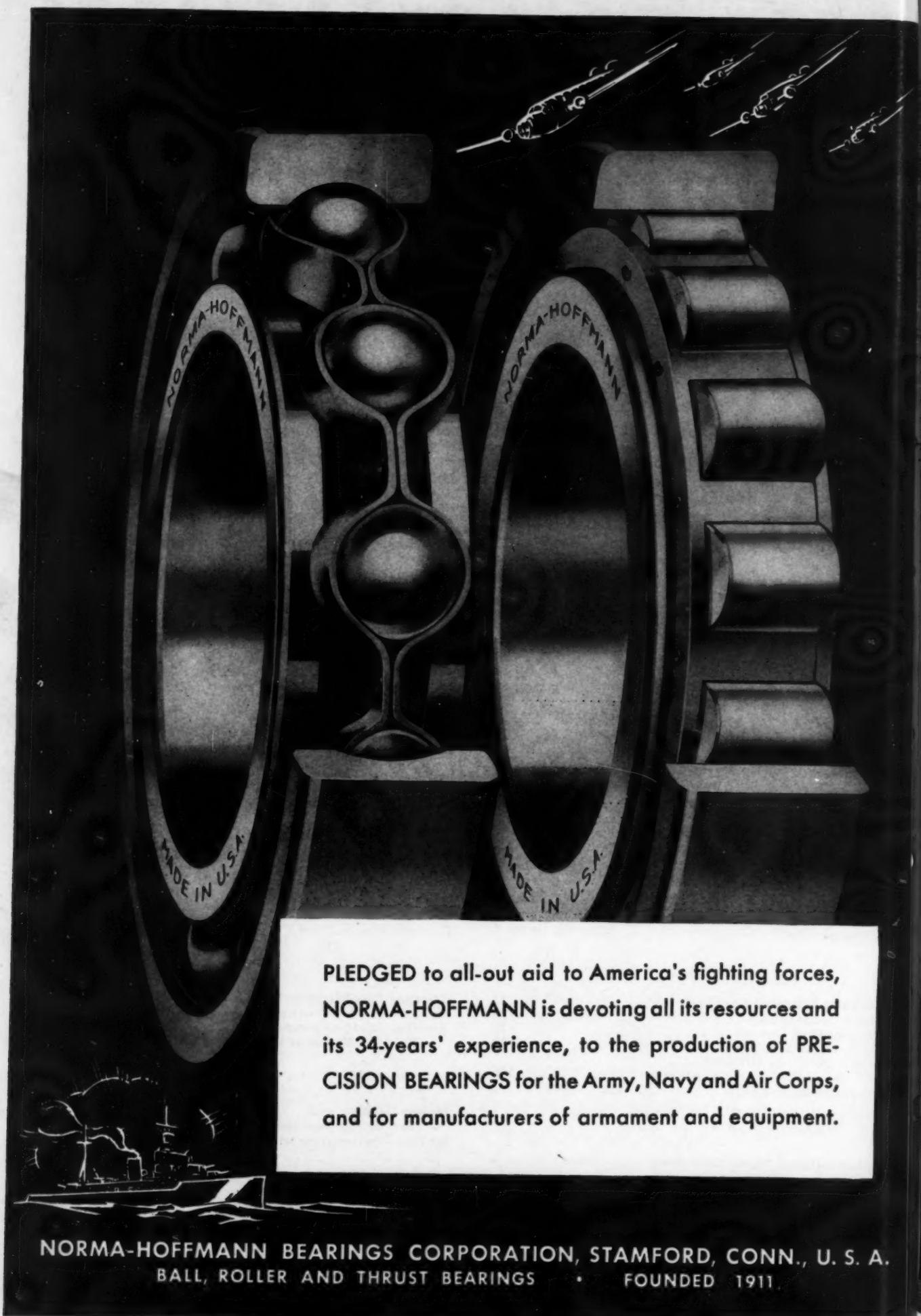

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BALL, ROLLER AND THRUST BEARINGS • FOUNDED 1911

EVERY DAY IN 1945—
EVERY FARVAL-EQUIPPED PLANT WILL

- ★ Eliminate labor of oiling
- ★ Cut shutdowns for repairs
- ★ Avoid waste of lubricant
- ★ Make bearings last longer
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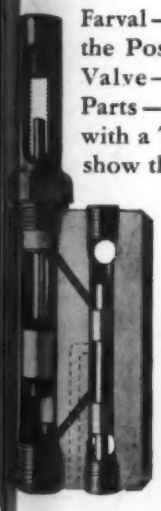

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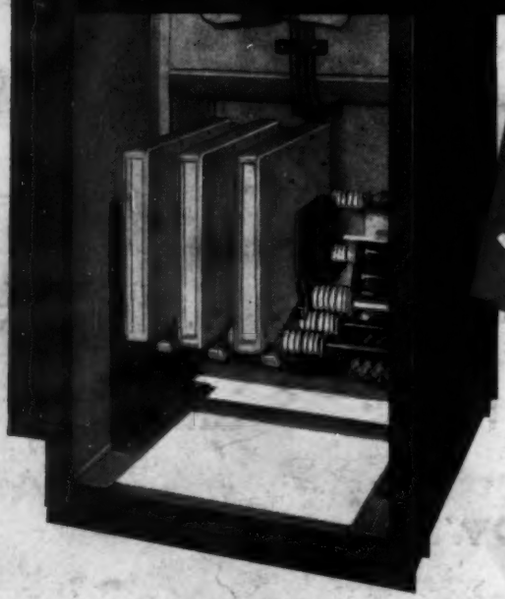

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